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Biology and abundance of alfonsino and bluenose off the lower east coast North Island, New Zealand

P. L. Horn and B. R. Massey

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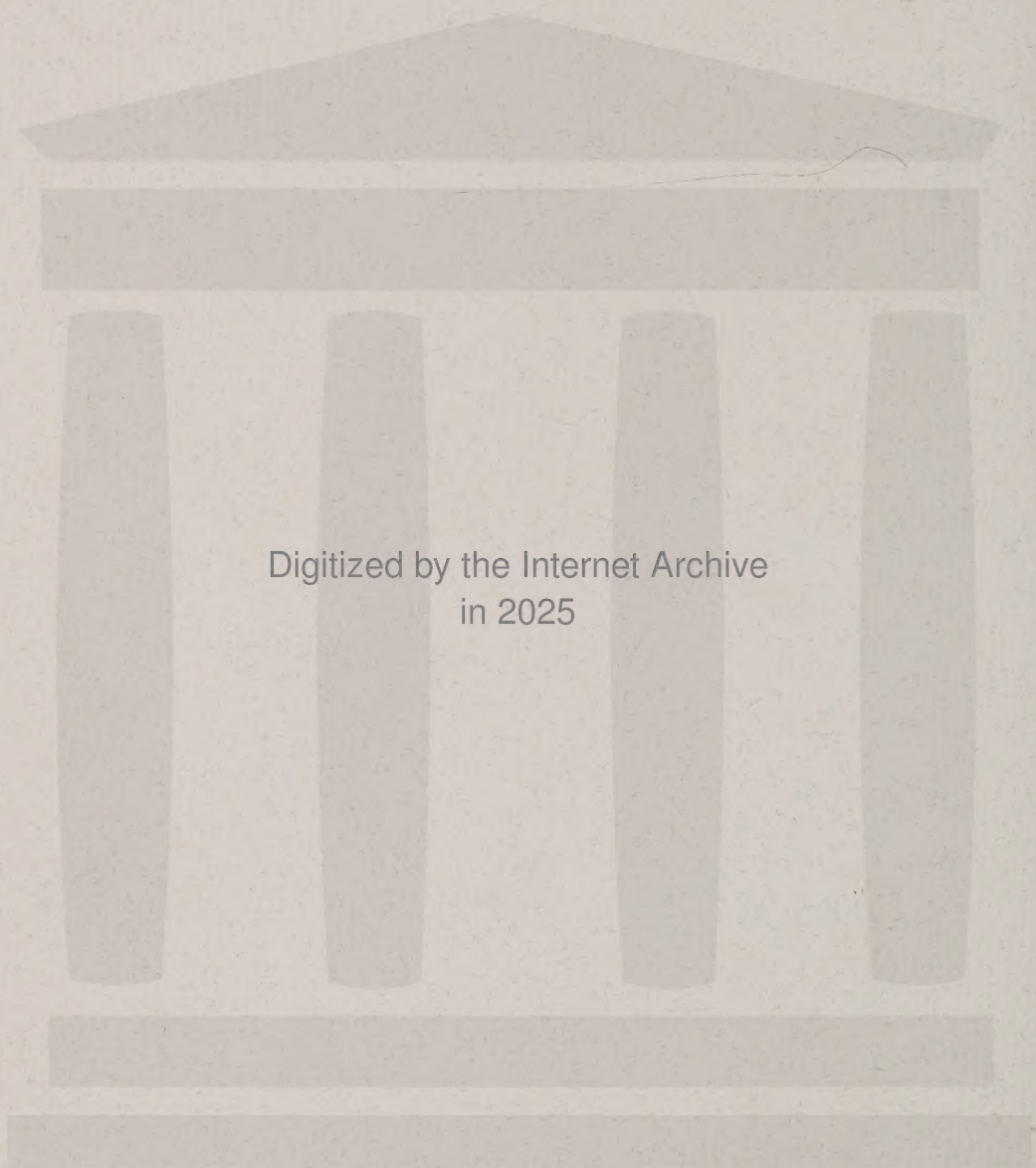

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Abstract

Horn, P. L. and Massey, B. R. 1989: Biology and abundance of alfonsino and bluenose off the lower east coast North Island, New Zealand. *N.Z. Fisheries Technical Report No. 15*. 32 p.

Aspects of the biology of alfonsino (*Beryx splendens*) and bluenose (*Hyperoglyphe antarctica*) off the lower east coast North Island, New Zealand were investigated. Age and growth were examined, and age frequencies varied between fishing grounds. Spawning did not appear to occur on any of the semipelagic trawl grounds; consequently, the reproductive cycles of both species remain poorly understood. Alfonsino are recruited into the commercial fishery at about age 4 y, and bluenose at about age 2 y. Steep slopes of catch curves for both species suggest that as the fish get older they move off the commercially exploited grounds to areas as yet unknown, hence estimates of mortality can not be derived. A combined trawl-acoustic survey and a video camera survey were tested as stock abundance survey techniques, but they were unsuitable. The analysis of catch per unit of effort data from the semipelagic trawl fishery appears to provide a satisfactory indication of relative abundance of alfonsino and bluenose on the trawl grounds. Stocks of both species appear to have declined substantially since the development of the trawl fishery.

Introduction

An investigation of the alfonsino (*Beryx splendens*) and bluenose (*Hyperoglyphe antarctica*) resources in the Central (East) Fisheries Management Area (FMA) (Figure 1) began in August 1985. The programme was established in response to the rapid development of a semipelagic trawl fishery for alfonsino off the Wairarapa coast; bluenose is a major associated catch in the fishery. There was some concern about the lack of information on the resources, and it was feared that these species might not be able to sustain the large increases in fishing pressure brought about by this new method.

The main aim of the investigation was to determine sustainable yields for alfonsino and bluenose in the Central FMA. Therefore, the biology and behaviour of these species was researched, and various biomass survey techniques were tested. Serious problems were encountered in both facets of the investigation. This report reviews the results obtained so far. Detailed reports on the age and growth of alfonsino (Massey and Horn in press) and bluenose (Horn 1988) have been prepared separately, as has a report on the tagging of alfonsino and bluenose with detachable hook tags (Horn 1989).

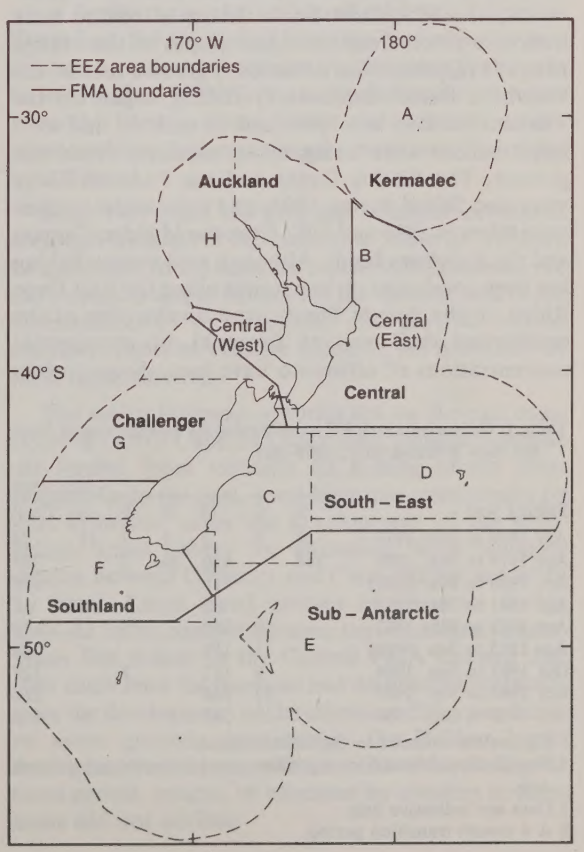

Figure 1: The New Zealand Exclusive Economic Zone (EEZ) areas (A–H) and the Fisheries Management Areas (FMA) (September 1986).

History of the fishery

Alfonsino

Before 1983 alfonsino were virtually unfished around New Zealand. Although the first domestic landings were recorded in 1981, foreign commercial vessels and research vessels had been catching alfonsino for many years, particularly on the Chatham Rise, though the total catch was generally small (Table 1).

The first domestic target fishing for alfonsino was in early 1983. Exploratory fishing on banks between Cape Palliser and Cape Kidnappers (Figure 2) during March, April, and May, by a vessel which used a conventional bottom trawl, yielded moderate catches of alfonsino. The motivation to develop the alfonsino fishery came from the introduction of a new French-designed semipelagic trawl which enabled fishing over foul ground, where most of the fish appeared to be (Cade *et al.* 1984). Catches rose rapidly with the successful use of this technique. Almost 1500 t of alfonsino were caught between Cape Palliser and Cape Kidnappers from December 1983 to June 1984. Up to nine vessels were participating in this fishery in 1985, but about five accounted for most of the landings.

Alfonsino are generally found on banks and seamounts. During 1983 and 1984, fishing effort was concentrated on the Palliser bank and, to a lesser extent, the Motukura Bank. Many alfonsino were bottom trawled from the upper slopes of the orange roughy (*Hoplostethus atlanticus*) ground east of the Kaiwhata Bank. Exploratory fishing began on the Tuaheni Bank in late 1984, and by early to mid 1985 large catches were being taken regularly from this ground. The Ritchie Banks and the Paoanui Ridge were also fished during 1985, and substantial catches were taken in 1986 and 1987 from the Madden Canyon and the Kaiwhata Bank. Although exploratory fishing has been conducted on seamounts along the East Cape Ridge, in the Bay of Plenty, and on the edge of the continental shelf west of Taranaki, no commercial concentrations of alfonsino have been discovered in these areas. Therefore, the target fishery is confined to the area between the Tuaheni Bank and the Palliser bank. Reported landings for each FMA for 1981–86 are given in Table 2.

Table 1: Estimated catch (t)* of alfonsino by foreign vessels from the New Zealand EEZ, 1978–86†

	EEZ area						
Fishing year	B	C	D	E	F	G	Total
Apr 1978 to Mar 1979	1	1	5	1	1	15	24
Apr 1979 to Mar 1980	164		520	20	3		707
Apr 1980 to Mar 1981‡			115				115
Apr 1981 to Mar 1982			62			4	66
Apr 1982 to Mar 1983		19	103		18		140
Apr 1983 to Sep 1983§		1	158				159
Oct 1983 to Sep 1984		9	117		2		128
Oct 1984 to Sep 1985		14	266				280
Oct 1985 to Sep 1986		10	543			5	558

* Figures are rounded to the nearest tonne.
† New Zealand Ministry of Agriculture and Fisheries unpublished data.
‡ Data are indicative only.
§ A 6 month transition period.

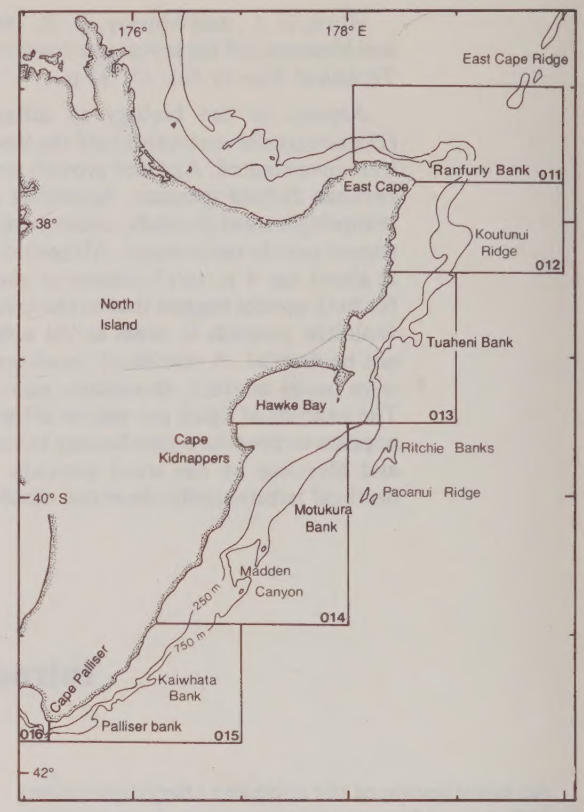

Figure 2: Lower east coast North Island, showing the major commercial grounds for alfonsino and bluenose and the fishing return areas 011–016.

Although alfonsino are caught primarily by midwater trawl, some are taken in the Central and Auckland FMAs as a bycatch of bottom trawl, setnet, and line fisheries. Recently, more alfonsino have been taken by lines because of the adoption of monofilament nylon for droppers and snoods.

Catches of alfonsino were unrestricted until the introduction of The Fisheries (Commercial Quotas) Regulations 1984, Amendment No. 1. This legislation set a quota of 180 t of alfonsino for the Central FMA between 1 June and 30 September 1985, and it was intended to hold the catch of this species at about 1500 t for the 1984–85 fishing year (the official fishing year is from 1 October to 30 September). As about 1300 t of alfonsino had been landed between October 1984 and May 1985, the legislation was thought necessary to avoid the desirable catch level of 1500 t being exceeded. From 1 October 1985 to 30 September 1986, the fishery was managed by individual quotas being allocated to fishers and companies according to

their catch histories (the average of the best two of the previous three years), the quotas being prorated down to 1500 t. From 1 October 1986 the fishery was managed under the individual transferable quota (ITQ) system. Total allowable catches (TAC) for alfonsino (including red bream, *Beryx decadactylus*) for the 1985–86 and 1986–87 fishing years are given in Table 3. Red bream are included in the alfonsino TAC because they are a bycatch species which are landed and sold as alfonsino.

Quota restrictions have meant that the annual catch of alfonsino has not increased since the 1985–86 fishing year. However, since 1983 there has been a substantial shift in fishing effort (Figure 3). Catches from the Palliser bank and the Motukura Bank have dropped dramatically, but those from the Tuaheni Bank, the Ritchie Banks, and the Paoanui Ridge have increased. According to the skippers operating in the fishery, these changes have occurred because of an apparent reduction in the amount of fish on the Palliser and Motukura grounds. There has also been an increase in the catch of bluenose relative to alfonsino. This has caused management problems in the fishery because bluenose are managed under the ITQ scheme. In addition, there was a change from mainly day fishing during 1983 and 1984 to almost entirely night fishing during 1986 and 1987. This probably resulted from an increased understanding of alfonsino behaviour by fishers.

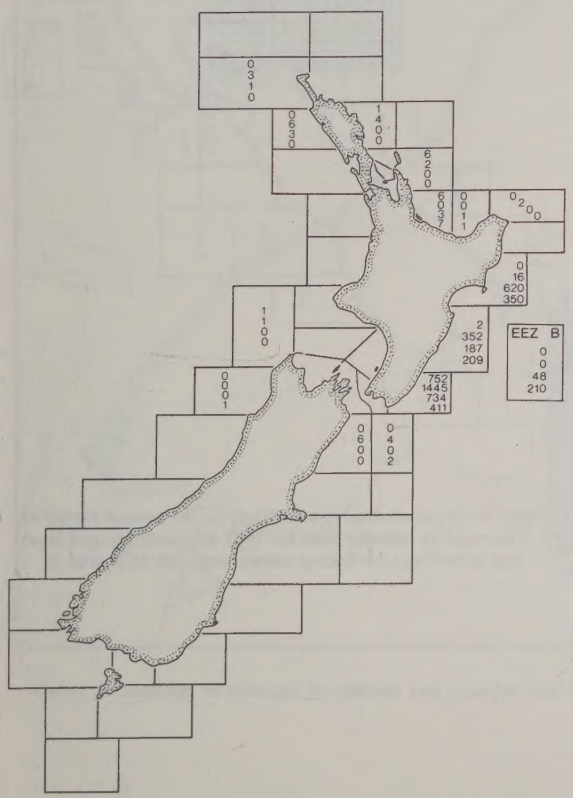

Figure 3: Reported domestic landings (to the nearest tonne) of alfonsino by calendar year for 1983–86 (landings read from top to bottom) by fishing return area and EEZ area B.

Table 2: Reported domestic landings (t) of alfonsino and bluenose for the calendar years 1981–86, from areas approximating each Fisheries Management Area (FMA)

FMA	1981	1982	1983	1984	1985	1986*
Alfonsino						
Auckland		0	15	15	9	9
Central		154	766	1 814	1 541	970
Challenger		0	1	19	0	1
Southern†		0	0	10	1	3
Area unknown‡	67	0	88	41	165	210
Total	67	154	870	1 899	1 716	1 193
Bluenose						
Auckland	146	246	250	464	432	440
Central	101	170	353	811	648	632
Challenger	12	22	47	30	26	53
Southern†	36	46	51	81	73	33
Area unknown			25	25	147	408
Total	295	484	726	1 411	1 326	1 566

* Landings were substantially underreported.

† Includes South-East, Southland, and Sub-Antarctic FMAs.

‡ Area unknown shows the quantity of fish recorded by EEZ area, or where no area information was supplied. Of the landings listed for area unknown in 1985 and 1986, respectively at least 48 and 210 t of alfonsino and 98 and 378 t of bluenose were taken from the Paoanui Ridge and Ritchie Banks east of fishing return area 014.

Bluenose

Bluenose have been landed by commercial line fishers at least since the 1930s (Graham 1953)..Before 1981, they were landed under various names and coded as hapuku (*Polyprion oxygeneios*). If landed as "bonita", they were reported separately, but in some years bonita were also confused with other species. Therefore, the amount of bluenose landed in the past can not be estimated accurately, though it is thought to be low (Paul 1985). Little target fishing for bluenose occurred because most fishers concentrated on the more traditional species, hapuku and bass (*Polyprion americanus*).

Since 1981 there has been a substantial increase in recorded landings of bluenose (*see* Table 2). This can be attributed to the separate reporting of bluenose, to the increased target fishing for the species, and to the development of the alfonsino and gemfish (*Rexea solandri*) fisheries because bluenose are a bycatch of both these fisheries.

The major bluenose grounds are on the east coast between North Cape and Kaikoura, though bluenose are landed from virtually all fishing return areas (Figure 4). In the past, most bluenose were caught by line. However, since the development of the semi-pelagic trawl fishery for alfonsino, most bluenose catches between Gisborne and Cape Palliser are taken by trawl. Large trawl catches of bluenose during 1984–85 led to conflict between trawl and line fishers. Many line fishers in the Central FMA claimed that their catch rates for bluenose had declined substantially since the development of the alfonsino fishery and that on some grounds (particularly the Palliser bank) fishing had become unprofitable. However, during the same period, catches of bluenose by trawlers in these areas did not decline.

In 1985 there was a suggestion of overexploitation of bluenose by line fishing in the Auckland FMA; fishers reported that they had to fish more distant grounds because catch rates had declined inshore.

Recently there have been two major developments in the bluenose fishery. Firstly, the introduction of the ITQ system gave fishers the opportunity to sell their bluenose quota. Many line fishers sold their quota either to the government in the tender rounds, or privately after they had received their final ITQ allocation. Consequently, in the Central FMA there are now few line fishers with bluenose quotas. Secondly, companies involved in the alfonsino trawl fishery had exceeded their 1986–87 quotas of bluenose by early January 1987. This was partly because of an apparent increase in the abundance of bluenose relative to alfonsino on the trawling grounds. Fishing methods had not changed, but the catch of bluenose was relatively greater than in previous years.

The catch distribution of bluenose remained fairly stable during 1983–86. The bluenose fishery is predominantly a summer-autumn one in the Auckland FMA, but no seasonal trends are apparent in other regions. The methods used to catch bluenose during 1983–86 in various regions around New Zealand are shown in Figure 5. Off the north coast North Island and off the west coast South Island, bluenose are mainly line-caught. In the east coast South Island fishery, line and setnet fishing are mostly used. In the Bay of Plenty, setnetting activity has increased to become more important than lining. Major changes have occurred off the east coast North Island, where there has been a substantial decline in lining and an increase in trawling. Most of the trawl catches in this area are taken by semipelagic trawl, whereas bluenose are a bycatch of bottom trawling in other regions.

No restrictions on catches of bluenose were imposed before June 1985. The rapid development of the alfonsino trawl fishery during 1984–85 caused concern that the attendant catch of bluenose might not be sustainable. Consequently, The Fisheries (Commercial Quotas) Regulations 1984, Amendment No. 1 was introduced to set a trawl quota of 110 t of bluenose in the Central FMA between 1 June and 30 September 1985. This measure was intended to hold the catch of bluenose in the Central FMA at about 700 t for the 1984–85 fishing year. A TAC for bluenose was then introduced for the 1985–86 fishing year. Although most TACs corresponded to reported landings from 1 July 1983 to 30 June 1984, the Central bluenose TAC was set below the 720 t landed during this period as a response to the reports of falling catch rates on the major bluenose grounds. Total allowable catches for 1985–86 and 1986–87 are given in Table 3. Changes made for the 1986–87 fishing year included an increase in the South-East and Southland (Southern) TAC and the setting of a TAC for the Kermadec FMA.

Table 3: Total allowable catches (TAC) (t) for alfonsino (BYX) and bluenose (BNS) for the 1985–86 and 1986–87 fishing years, by Fisheries Management Area (FMA)

	1985–86		1986–87	
FMA	BYX	BNS	BYX	BNS
Auckland	20	440	10	450
Central	1 500	655	1 530	680
Challenger	0	60	30 (10)*	60
South-East and Southland	240	75	220 (160)*	150
Kermadec			10	10

* Foreign allocations of quota in addition to the domestic TAC.

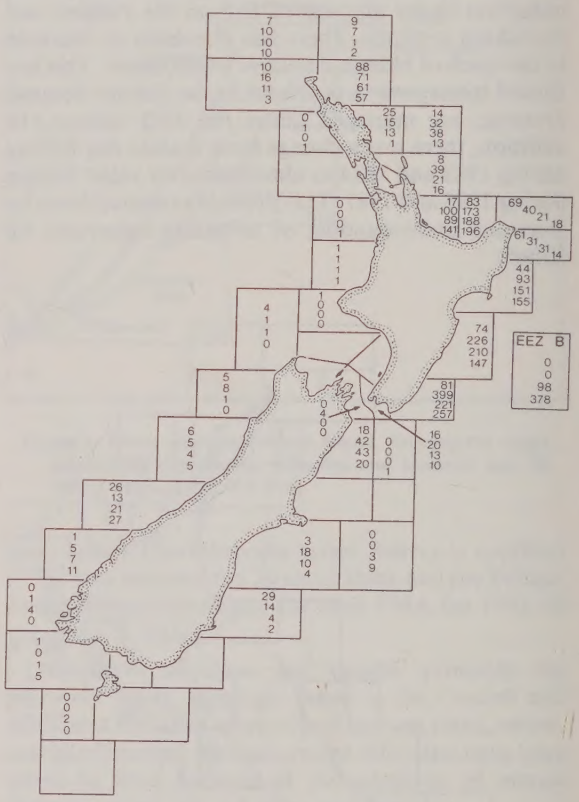

Figure 4: Reported domestic landings (to the nearest tonne) of bluenose by calendar year for 1983–86 (landings read from top to bottom) by fishing return area and EEZ area B.

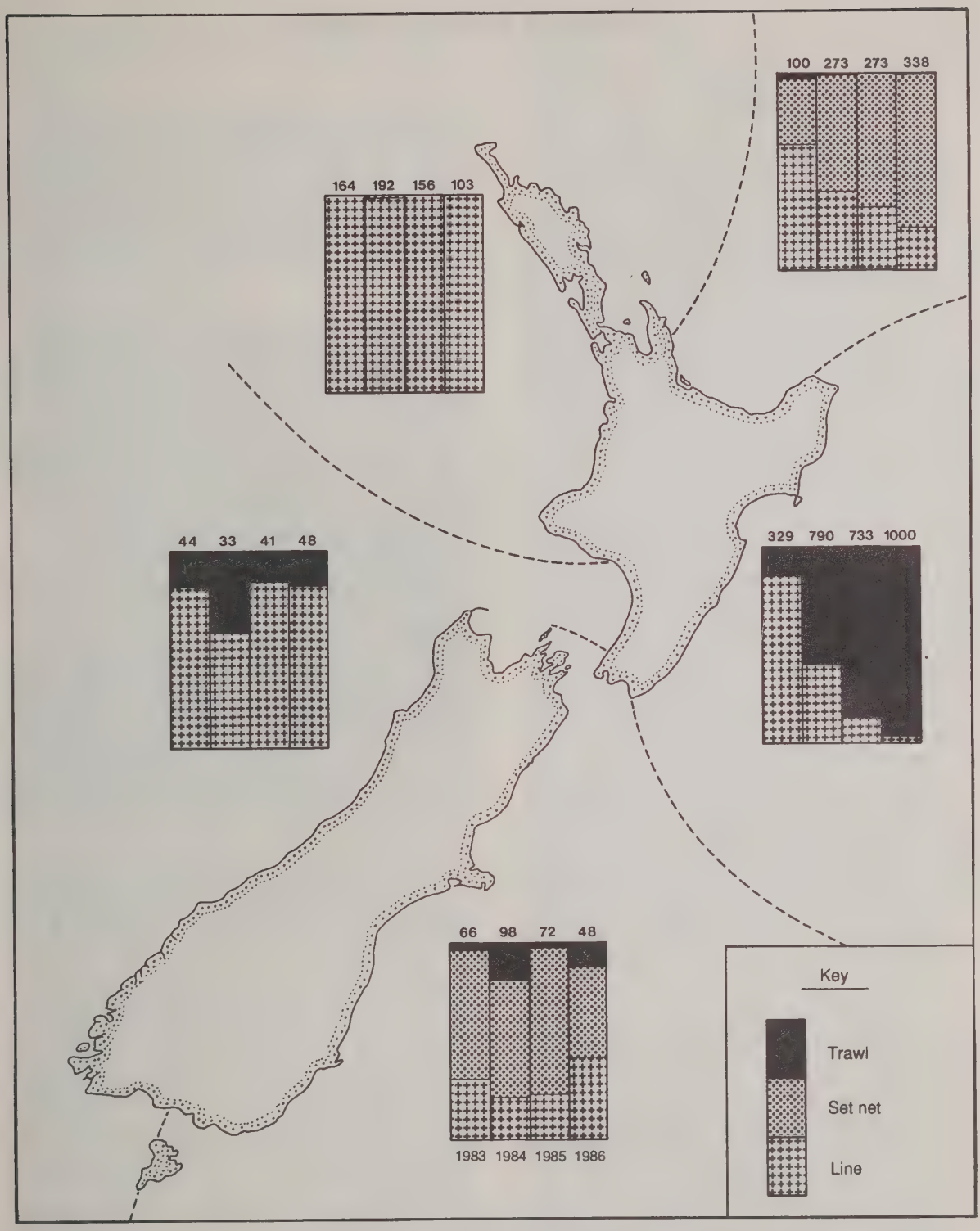

Figure 5: Landings of bluenose by method and calendar year for 1983–86. (Total reported landings (t) are shown above the bars.)

Review of biological data

Alfonsino

Busakhin (1982) reviewed the published records of alfonsino and red bream and found that these species are widespread throughout the world's tropical and temperate waters. However, the depth range at which they are found varies substantially for both species. In some areas they are found in very shallow water (e.g., as shallow as 25 m for alfonsino off the coast of Oman in the Indian Ocean), whereas in other areas they are found in very deep water (e.g., down to 1200 m for alfonsino in the southwest Atlantic Ocean). In New Zealand, alfonsino are generally found between 200 and 1000 m, but they appear to be most abundant between 300 and 500 m (Francis and Fisher 1979, Ayling and Cox 1982, New Zealand Ministry of Agriculture and Fisheries (MAF) unpublished data). Iguchi (1973), Yamamoto *et al.* (1978), and Seki and Tagami (1986) reported that alfonsino size increased with depth. A similar trend was observed on the Chatham Rise in 1979 (Kerstan and Sahrhage 1980).

Alekseev *et al.* (1986) examined length frequency distributions and sexual maturity stages of alfonsino from various areas in the north and south Atlantic. They suggested that at least three separate populations of alfonsino existed in the Atlantic, each in a large oceanic eddy system. In each system there was a reproductive zone, where large fish predominated and spawning occurred, and a "vegetative" zone, where juveniles and first-maturing fish were found. Currents carried the eggs and larvae from the reproductive to the vegetative zone, and then the first-maturing fish migrated back with the current to the reproductive zone, where they remained. However, Uchida and Tagami (1984) found that size frequency distributions from areas only short distances apart can differ greatly, and they are not always related to differences in depth. Therefore, the cyclical systems proposed by Alekseev *et al.* (1986) are not always present.

Alfonsino show strong diurnal migratory behaviour. Galaktionov (1984) stated that the fish are densely distributed on the bottom during the day (though not visible on the echosounder), and that they form large schools at dusk and ascend into midwater before dispersing. The fish feed while dispersed in midwater (Uchida and Tagami 1984). Schools form again at dawn and descend to the bottom where the fish spread out. Juvenile and adult fish show the same behaviour, though some modifications are apparent during the spawning period. Masuzawa *et al.* (1975) briefly alluded to a similar pattern of daily migration for Japanese alfonsino, as did Darnitsky (1985) for fish on the Hawaiian Seamount Chain. However, Darnitsky found that the vertical movement was not related to feeding, but was possibly caused by upward currents.

Tagging studies show that alfonsino do not migrate over wide geographical areas in the short term (< 1 y). Of the 146 fish recaptured from 3925 fish released in a Japanese tagging study, only 26 had moved from their tagging site, even though many were free for more than a year (Masuzawa *et al.* 1975). Most fish had moved from higher to lower latitudes, which was thought to represent a return to their natal areas for spawning. A longer term drift from higher to lower latitudes was suggested by length and age composition data.

Alfonsino spawn from summer to early autumn (i.e., from June to October) in waters near Japan, in the northwest Hawaiian Islands, and in the northeast Atlantic (all lying from a latitude of 30 to 36° N) (Masuzawa *et al.* 1975, Sherstyukov and Nostov 1986, Uchida and Uchiyama 1986). In the southeast Atlantic, they spawn from January to March (Alekseev *et al.* 1986). Alfonsino reproduce in the areas they normally inhabit. They are serial spawners and first spawn at about 34 cm fork length (FL) or 4 y in Japanese waters (Masuzawa *et al.* 1975). Each season, 10–12 spawning bouts occur, each about 4 days apart (Alekseev *et al.* 1986). Eggs are free floating and hatch in about 1 day at 23 °C, or 6–8 days at 5–10 °C. Onishi (1968) and Masuzawa *et al.* (1975) described the egg and larval development of alfonsino up to 10 days after hatching. Mundy (in press) recently described the larval development to a more advanced stage. The pelagic larvae are widely distributed by surface currents until they adopt a demersal existence, possibly when they are about 1 y old (Chikuni 1971). Ivanin (1987) reported the capture of 5–10 cm FL alfonsino from the epipelagic zone in the Indian Ocean (they were taken 50–210 m below the surface in waters deeper than 2000 m).

In Japan, growth studies using several techniques have been conducted on alfonsino (Ikenouye and Masuzawa 1968, Ikenouye 1969, Masuzawa *et al.* 1975). Although the results of the studies were often dissimilar, and none of the aging methods were validated satisfactorily (Massey and Horn in press), all of the studies suggested moderate growth rates (32–37 cm FL at 5 y). Another study which was not validated, on central west Atlantic alfonsino by de Leon and Malkov (1979), also suggested moderate growth rates (31–35 cm FL at 5 y). A comparative study of alfonsino from the southeast Atlantic, the northeast Pacific, and the northwest Indian Oceans, showed that there was little difference in growth rates between fish from these three areas (Kotlyar 1987). In this study, Kotlyar concluded that alfonsino from the Indian Ocean laid down two otolith rings annually.

There are few data on recruitment and natural mortality. Masuzawa *et al.* (1975) stated that recruitment of young fish into the Furase fishing ground occurred around autumn to early winter each year, which suggests seasonal rather than continuous recruitment. The recruited fish were 24–26 cm FL and were considered to be 2 y old. Kotlyar (1987) found

1 y fish already recruited into their demersal phase in the Pacific, Atlantic, and Indian Oceans, but full recruitment did not appear to occur until the fish were 2–3 y.

Masuzawa *et al.* (1975) calculated survival rates for alfonsino from tagging experiments and age composition data. No attempt was made to estimate the natural mortality rate because neither tag-induced mortality, nor tag loss, were estimated. Age composition data could not be used to estimate mortality rates because age composition varied substantially between grounds and migration patterns were not adequately understood.

Crustaceans and fish are the most important constituents of the alfonsino diet. In one study done on the Emperor Seamount Chain, small fish predominated in 43% of the alfonsino stomachs examined, and crustaceans (decapods, mysids, and euphausiids) predominated in 37% (Aomori Prefectural Fisheries Experimental Stations 1976, cited by Uchida and Tagami 1984). In another study in Japanese waters, fish were present in 48% of the alfonsino sampled, crustaceans (including euphausiids, isopods, shrimps, and amphipods) in 36%, and squid (*Nototodarus* spp.) in 14% (Masuzawa *et al.* 1975). Proportions of dietary components varied between grounds.

Alfonsino appear to be vulnerable to overfishing. Sasaki (1986) found a substantial decline in catch per unit of effort (CPUE) in the Hawaiian Seamount Chain after only 4 y of intensive fishing. Yamamoto (1986) also found declining catch rates on several Japanese seamounts after large increases in lining effort. The susceptibility of alfonsino to overfishing may be due to their schooling behaviour and their moderately slow growth.

Virtually no information is available on the biology of red bream. The species is similar in appearance to alfonsino, though the body is slightly deeper, and the fish average between 20 and 40 cm FL. Young fish have a long filamentous dorsal ray (Ayling and Cox 1982) and are thought to live in midwater for at least their first year. They appear to grow rapidly up to 25 cm FL, after which they adopt a deepwater bottom-dwelling existence and have a fairly slow growth rate (Wheeler 1969).

Bluenose

Bluenose are large fish which are widespread in the southern oceans; they occur off the coasts of New Zealand, southern Australia, Tasmania, South Africa, and Tristan da Cunha in the southern Indian Ocean (McDowall 1982). They are widely distributed in New Zealand waters from 100 to 500 m. They prefer rough rocky ground, though small schools of similarly sized small individuals occur in more open areas. Winstanley (1978, 1979) suggested that bluenose off the southeast coast of Australia are found near the bottom at night, and that they move off the bottom to feed on midwater organisms during the day. The pelagic tunicate *Pyrosoma atlanticum* appears to be the main dietary component of bluenose in Australian waters (Winstanley 1978, 1979, Jones 1985). Graham (1953) found that benthic fish and crustaceans form a large part of the diet of Otago bluenose, which suggests that these bluenose have a broader feeding behaviour than those described by Winstanley.

The biology of bluenose is poorly understood. Preliminary studies off Tasmania and South Australia suggested that most fish first spawned at about 62 cm FL (Webb 1979), probably about late April (Jones 1985). Webb's (1979) growth curve suggests that growth for the first 2 y is rapid, but later slows, and sexual maturity is reached at 6–7 y. Despite the initial period of fast growth, bluenose appear to be long-lived. Juveniles are rarely found, and it seems likely that the young are surface living, as they are for other stromateoids, including some species of *Hyperoglyphe* (Haedrich 1967, Horn 1970).

Biological investigations

The main aim of the biological investigations was to determine the productivity of alfonsino and bluenose. Estimates of productivity are needed to determine the percentage of the total biomass that can be harvested annually without dangerously depleting the stock. Specific objectives for both bluenose and alfonsino were to determine:

1. the size structure and sex composition of commercial catches;
2. a suitable aging technique and validate it;
3. the growth rate, age structure, and natural mortality rate for each sex;
4. the timing of reproduction;
5. the size and age at maturity;
6. the fecundity of females.

Materials and methods

A commercial catch sampling programme was initiated to collect biological data on alfonsino and bluenose over at least 12 months. Stock boundaries for both species were unknown at the time sampling began. To ensure that all samples came from the same population (especially for age validation studies), samples were only taken from fish caught on the Palliser bank. (This ground was chosen because it is the closest ground to Nelson (where virtually all vessels in this fishery are domiciled) and was therefore searched first on each fishing trip. Consequently, catches were taken more frequently from the Palliser bank than from any other ground.)

Catch samples were collected 10 times for alfonsino and 9 times for bluenose between October 1985 and November 1986 (Table 4). The interval between sampling ranged from 3 to 11 weeks. The catches were all taken by commercial trawlers which used semipelagic trawl nets with 125 mm mesh codends. Most of the catches were taken by the same fishing vessel (*Resolution II*).

Additional samples from other fishing grounds were taken opportunistically throughout the year to study the biological characteristics of other fish populations. These samples were taken by various vessels, some of which did not use semipelagic nets.

During the main sampling programme, each sample was collected over 2 days; 1 day being spent sampling alfonsino and 1 day sampling bluenose. Fish were selected at random from the samples and measured to the nearest centimetre below actual fork length. Most fish were also weighed and sexed. Weight was measured to the nearest 0.1 kg below actual weight with a 5 or 25 kg spring balance. Sagittal otoliths were collected from five bluenose and seven alfonsino of each sex in each 1 cm size class. All fish which had their otoliths removed were weighed and sexed. Ten fish of each sex in each 5 cm size class ($\leq$ 29, 30–34, 35–39, 40–44, $\geq$ 45 cm for alfonsino and 50–54, 55–59, 60–64, 65–69, $\geq$ 70 cm for bluenose) also had their gonads staged and weighed on an Ohaus triple beam balance to the nearest 0.1 g (Table 5). Another 10 fish of each sex in each 5 cm size class had their gonads staged only. Whole ovaries from stage 3 fish were collected to determine size related fecundity.

Table 4: Details of all alfonsino (BYX) and bluenose (BNS) samples collected

Sample date	Sample size BYX	Sample size BNS	Ground	Vessel	Method
Main programme					
4/10/85	2 167	548	Palliser	*Waipori*	Midwater trawl
8/11/85	2 111	403	Palliser	*Resolution II*	Midwater trawl
10/12/85	1 663	684	Palliser	*Resolution II*	Midwater trawl
12/02/86	178	61	Palliser	*Marine Star II*	Midwater trawl
5–20/03/86	1 657	761	Palliser	*Resolution II*	Midwater trawl
14/05/86	712	0	Palliser	*Resolution II*	Midwater trawl
26/06/86	1 621	361	Palliser	*Resolution II*	Midwater trawl
18/08/86	71	61	Palliser	*Lady Kay*	Midwater trawl
9/09/86	1 503	566	Palliser	*Resolution II*	Midwater trawl
20/11/86	1 498	0	Palliser	*Resolution II*	Midwater trawl
30/11/86	0	348	Palliser	*Wanaka*	Midwater trawl
Opportunistic samples					
14/04/84	322	1 222	Palliser	*Wanaka*	Midwater trawl
18/04/85	80	0	Palliser	*Wanaka*	Midwater trawl
14/09/85		58	Tuaheni	*Marine Star II*	Midwater trawl
2/10/85	1 323	97	Tuaheni	*Marine Star II*	Midwater trawl
6/02/86	72	8	Tuaheni	*Marine Star II*	Midwater trawl
10/03/86	816	275	Tuaheni	*Resolution II*	Midwater trawl
14/05/86	505	0	Tuaheni	*Resolution II*	Midwater trawl
26/02/87	0	370	Tuaheni	*Kotare*	Trot line
8–20/03/86	231	469	Motukura	*Resolution II*	Midwater trawl
19/05/86	255	112	Motukura	*Resolution II*	Midwater trawl
26/06/86	224	0	Motukura	*Resolution II*	Midwater trawl
3/11/86	221	189	Motukura	*Resolution II*	Midwater trawl
16/03/87	0	129	Motukura	*Kotare*	Trot line
14/05/86	0	496	Paoanui	*Resolution II*	Midwater trawl
13/01/87	0	23	Paoanui	*Resolution II*	Midwater trawl
28/02/87	0	193	Paoanui	*Kotare*	Trot line
26/05/86	0	187	Lachlan	*Kotare*	Trot line
10/09/85	248	111	Madden	*Sea Reaper*	Bottom trawl
17/02/86	0	203	Madden	*Twofold Bay*	Bottom trawl
9/04/86	223	195	Madden	*Westerner*	Bottom trawl
13/06/86	235	167	Madden	*Westerner*	Bottom trawl
2/12/86	148	0	Kaiwhata	*Wanaka*	Midwater trawl
1979–80	0	266	East Cape		Line

Table 5: Criteria for assessing reproductive stages of female and male alfonsino and bluenose

Stage	Female	Male
1	Immature or resting, ovary clear or pink, no oocytes visible;	Immature or resting, testes small and threadlike;
2	Ovary pink, small oocytes visible against light;	Maturing, testes increased in size, but no milt expressible;
3	Orange yolk-filled oocytes present;	Spermiated, viscous milt present;
4	Hyaline oocytes present;	Spermiated, hydrated, free-flowing milt present;
5	Ovulated, eggs flow freely when light pressure applied to abdomen;	Spent, testes "bloody", no milt expressible.
6	Spent, ovary flaccid and "bloody", residual eggs present in oviduct;	
7	Atretic, degenerating or resorbing eggs present, ovary brown or black.	

Although the intention was to collect 10 ovaries from each 5 cm size class, few stage 3 fish were found and this was not possible. Gonadosomatic indices (GSI) (i.e., gonad weight as a percentage of total body weight) were calculated.

The amount of data collected from opportunistic samples varied according to the amount of time available.

Results and discussion

Alfonsino

Length frequency

Length frequency distributions of the Palliser bank samples taken during the main catch sampling programme were generally similar. They had a mode of 31–33 cm and a sharp logarithmic decline with increasing fish size (Figure 6).

Comparison of length frequency distributions of samples from all other grounds (Figure 7) with those from the Palliser bank, shows that the size frequency of alfonsino varies substantially between grounds. Fish on the Palliser bank and the Motukura Bank were generally small, whereas larger fish predominated in the Madden Canyon and on the Tuaheni Bank. On the Kaiwhata Bank, fish showed intermediate length characteristics, though the sample size was small. Reports from fishers suggest that fish caught on the Paoanui Ridge are usually large.

Samples from the Palliser bank, the Madden Canyon, and the Motukura Bank showed little variation over time. Fish from the Tuaheni Bank were generally large when catch rates were high and small when catch rates were low. However, other grounds may have shown similar results if sampled when few fish were present.

The April 1984 Palliser bank sample is different from any sample taken during the 1985–86 programme. The difference cannot be resolved because this is the only Palliser bank sample taken before 1985, and the April 1985 sample is similar to the later samples taken from this ground.

The length frequency distributions suggest that over fairly short periods alfonsino do not migrate. Therefore, when fish are not abundant on the Palliser bank, it is unlikely that they have migrated to the Madden Canyon or the Tuaheni Bank. However, the different length frequency structures of populations on different grounds suggest that over longer periods some age specific migration probably occurs. Masuzawa *et al.* (1975) concluded that migration between grounds resulted in an apparent increase in alfonsino size with decreasing latitude and increasing distance offshore.

Sex ratio

Sex ratio by size class for each sample from the Palliser bank and the Tuaheni Bank is shown in Figure 8. Sex ratios were estimated for each sample and tested for significance against the ratio of 1 : 1 (Table 6). If the catchability of males and females is equal for all length classes, then the ratio should give the relative proportions of each sex on the grounds at the time of sampling.

Table 6: Sex ratio (M : F) of alfonsino and bluenose samples

	Alfonsino		Bluenose	
Sample date	*n*	Ratio	*n*	Ratio
Palliser bank				
Apr 1984	–	–	1 222	1 : 1.28†
Oct 1985	1 345	1 : 1.22*	513	1 : 1.18*
Nov 1985	800	1 : 1.00	403	1 : 1.12
Dec 1985	807	1 : 0.99	513	1 : 1.04
Feb 1986	178	1 : 1.25	61	1 : 0.74*
Mar 1986	1 024	1 : 0.91	761	1 : 1.24†
May 1986	712	1 : 1.12	–	–
Jun 1986	702	1 : 1.22*	361	1 : 0.90
Aug 1986	71	1 : 0.51*	–	–
Sep 1986	497	1 : 1.14*	627	1 : 1.02
Nov 1986	527	1 : 0.81*	348	1 : 0.81*
Tuaheni Bank				
Sep 1985	744	1 : 0.66*		
Feb 1986	74	1 : 0.95		
Mar 1986	702	1 : 0.98		
May 1986	505	1 : 1.73*		
Motukura Bank				
Mar 1986	231	1 : 0.72*	352	1 : 0.85*

* Significantly different ($P < 0.05$) from a 1 : 1 ratio.
† Significantly different ($P < 0.01$) from a 1 : 1 ratio.

The male to female ratio did not depart significantly from 1 : 1 on the Palliser bank between November 1985 and May 1986, but it was significantly different between June 1986 and November 1986. However, during the latter period neither sex was consistently dominant. The proportion of females was lowest when fish were scarce and were thought to be spawning (August); this was also seen in the Tuaheni Bank data for September 1985. However, this observation is only tentative because the August 1986 Palliser bank sample size was low and there were only four samples from the Tuaheni Bank.

Age and growth

Studies on aging techniques, growth rates, and age structures suggest that counting growth checks in otoliths is probably a valid method for aging alfonsino (Massey and Horn in press). Alfonsino growth on the Palliser bank is moderate; males reach about 31, 39, and 42 cm at 5, 10, and 15 y respectively, and females reach about 32, 41, and 46 cm respectively at the same ages. Maximum recorded ages were 16.8 y for females and 15.8 y for males, and age specific mortality did not occur.

The age structures of commercial catches were reasonably stable on the Palliser bank from October 1985 to November 1986 (Massey and Horn in press). However, they appeared to vary greatly between grounds, which suggests that some age specific migration occurs. The probable occurrence of this migration makes it impossible to estimate the natural mortality rate at present; this problem was also encountered by Masuzawa *et al.* (1975). On the Palliser bank, 5 y old fish were fully recruited into the commercial fishery from February to July (late summer to early winter). On the Furase ground, 2 y old fish were recruited from late autumn to early winter (Masuzawa *et al.* 1975).

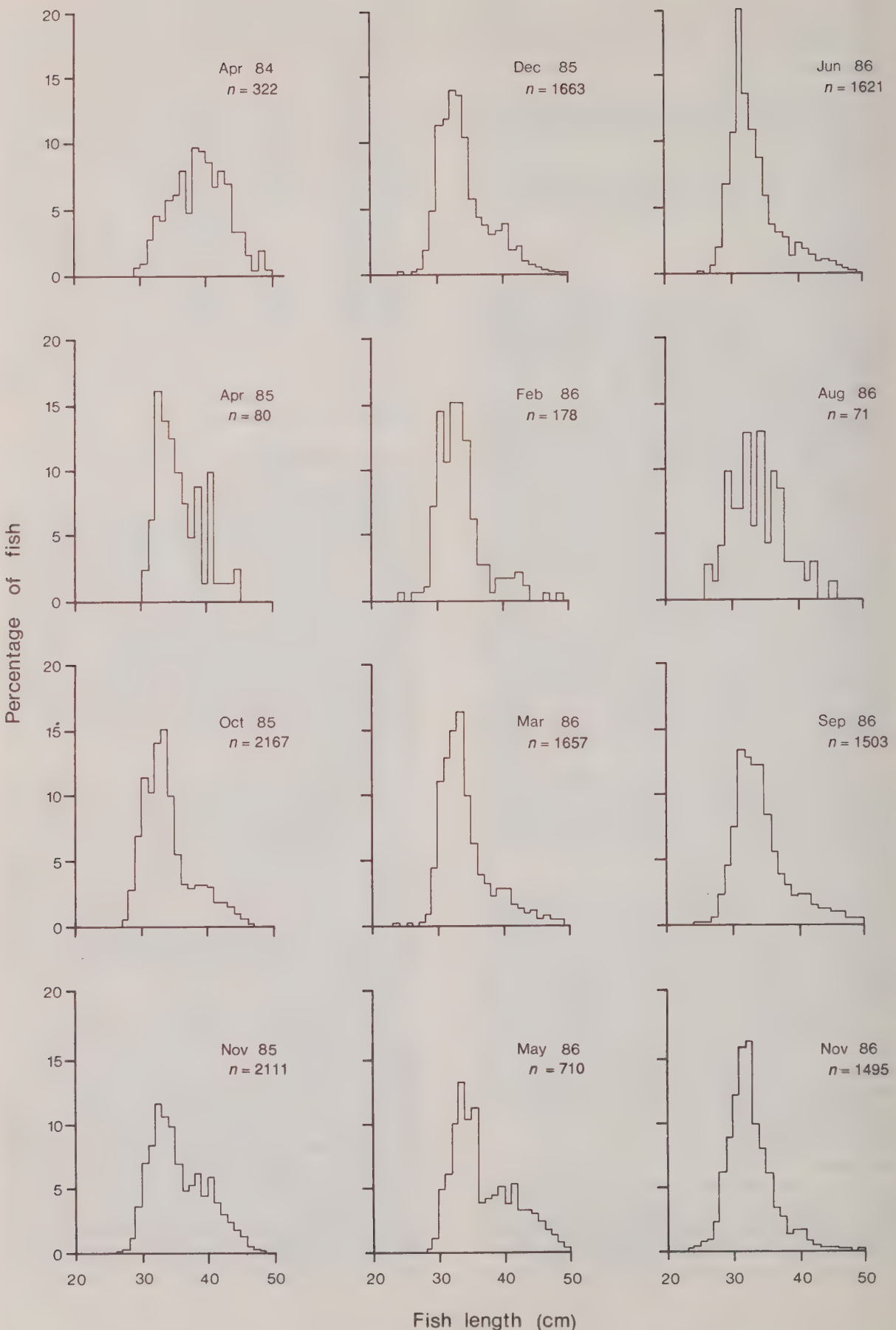

Figure 6: Length frequency histograms of alfonsino samples from the Palliser bank.

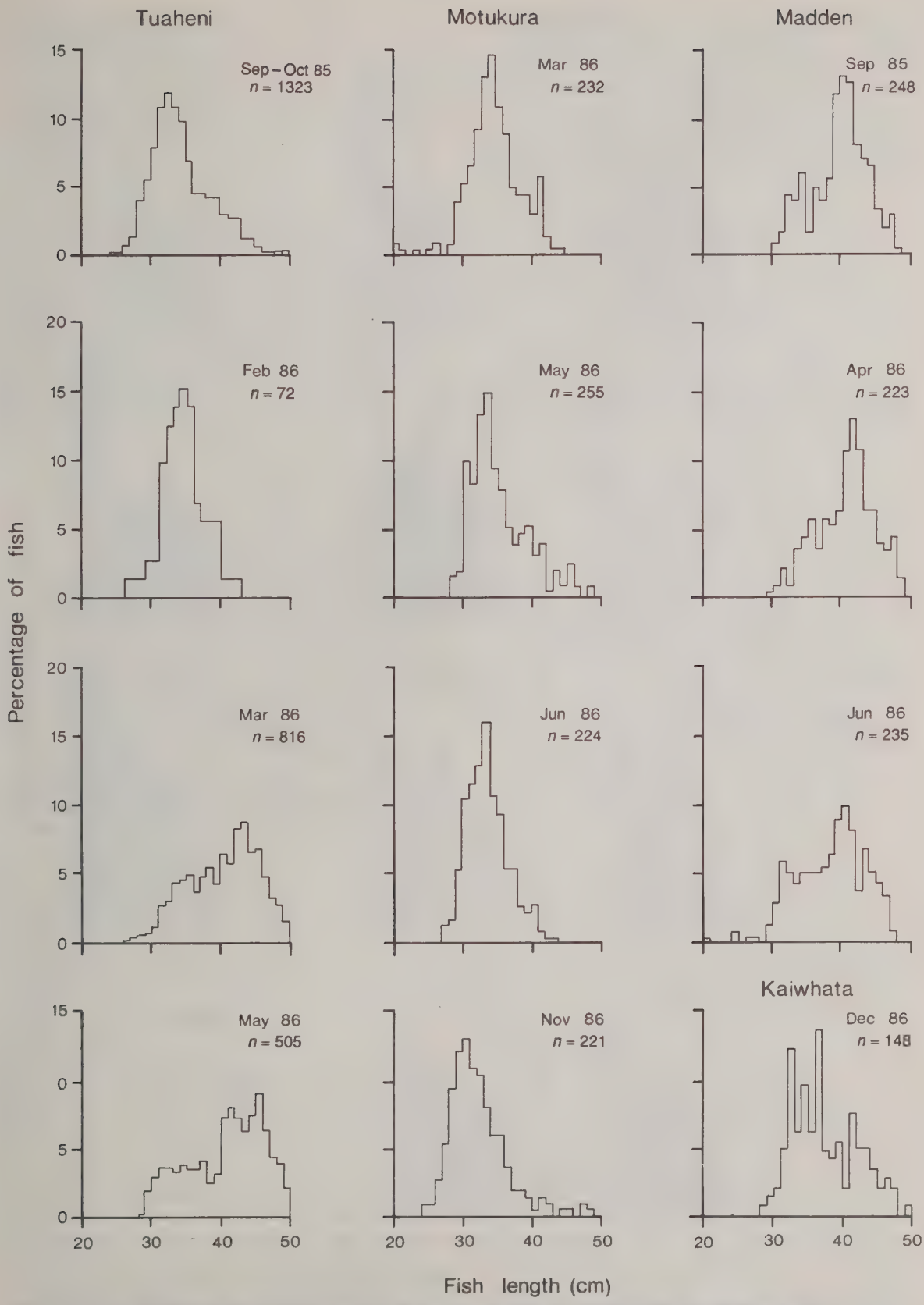

Figure 7: Length frequency histograms of alfonsino samples from all grounds except the Palliser bank.

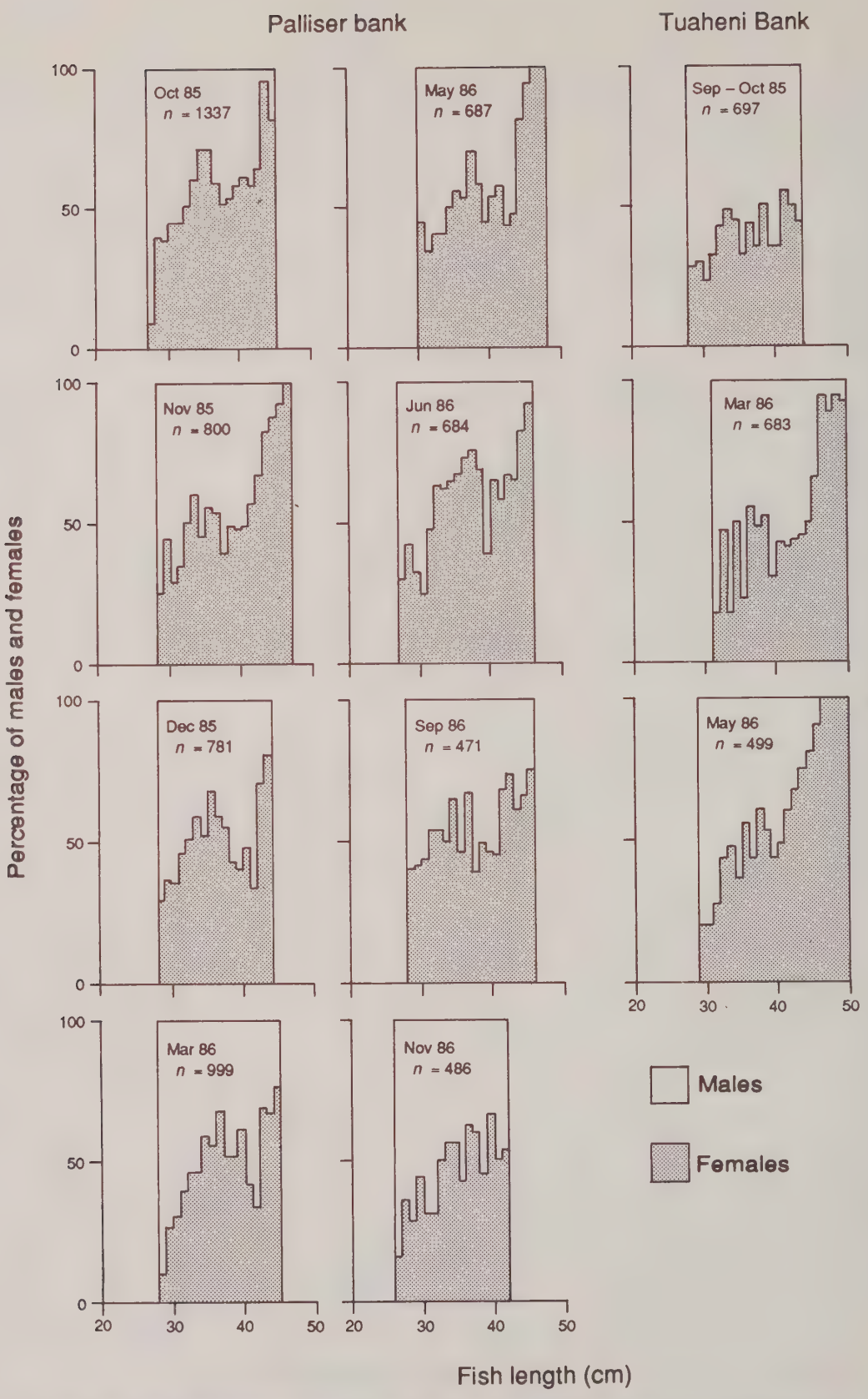

Figure 8: Sex ratios of alfonsino samples from the Palliser bank and the Tuaheni Bank, by 1 cm length classes. (Data are shown only when 10 fish or more are present in any length class.)

Reproductive biology

Most fish examined during the catch sampling programme were in the resting or immature reproductive stage (stage 1). Few fish with developing gonads (stage 3) were found at any time of the year, and no running ripe fish were found. Thus, the timing of reproduction and the size or age at maturity could not be determined accurately.

The percentage of stage 3 fish in each length and age class for each sample is shown for male and female fish in Figures 9 and 10. Stage 3 males were present in all length and age classes of most samples throughout the year, though few of these males were less than 5 y, or less than 30 cm. There was no apparent peak at any time of the year, and the only obvious trend was that the percentage of stage 3 males generally increased with age and length. The female length and age classes also did not show a single peak when all classes were combined. However, when the two size classes which produced stage 3 fish were combined (≥ 40 cm), there was a peak in June. The percentage of fish containing developing eggs also increased with size and age.

Gonadosomatic indices were plotted by length and age class for male and female fish from each Palliser bank sample (Figures 11 and 12). A one-way analysis

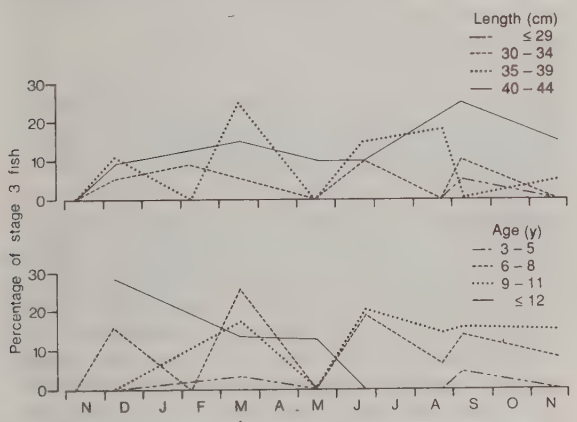

Figure 9: Monthly percentages of male alfonsino with stage 3 gonads from each Palliser bank sample, by length class and age class.

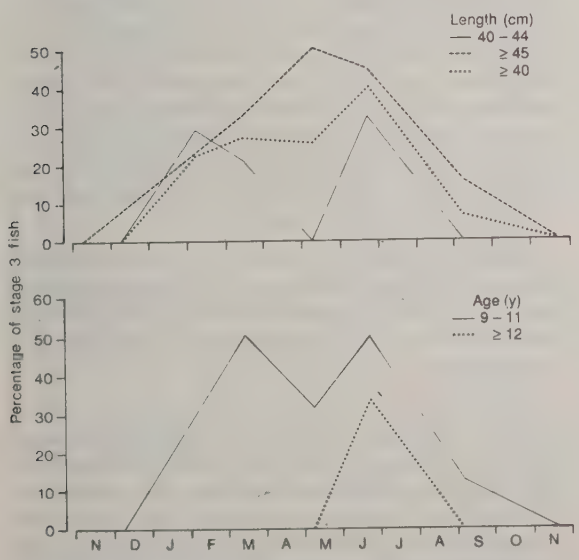

Figure 10: Monthly percentages of female alfonsino with stage 3 gonads from each Palliser bank sample, by length class and age class.

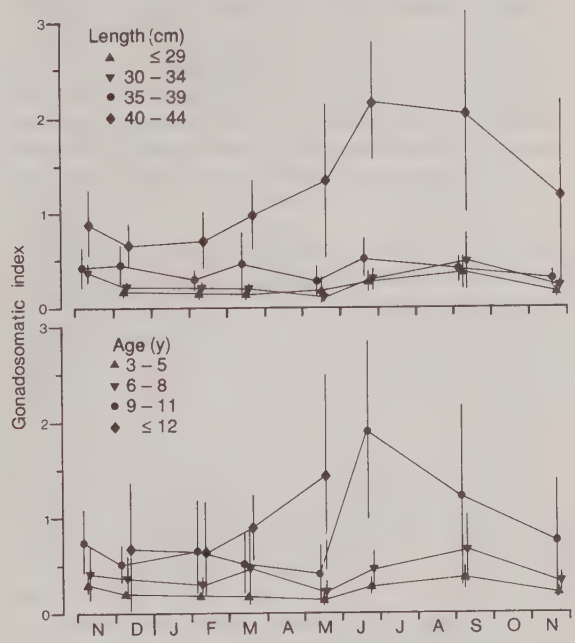

Figure 11: Monthly mean gonadosomatic indices for male alfonsino from each Palliser bank sample, by length class and age class. (Vertical bars show 95% confidence intervals.)

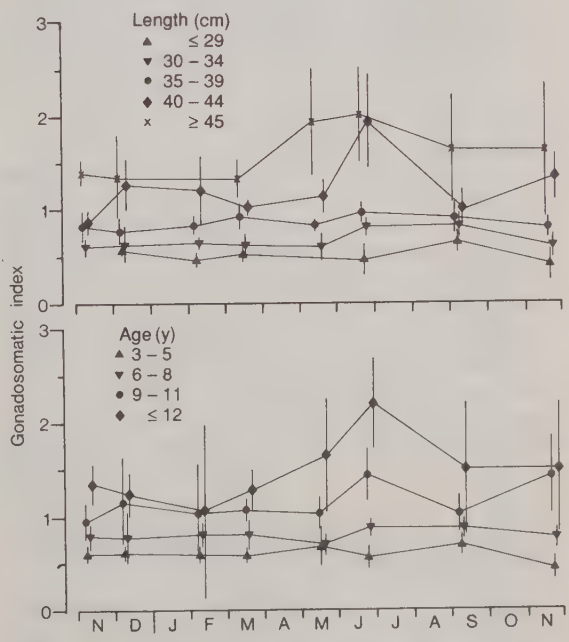

Figure 12: Monthly mean gonadosomatic indices for female alfonsino from each Palliser bank sample, by length class and age class. (Vertical bars show 95% confidence intervals.)

of variance (ANOVA) to test for differences in GSI over time was carried out on the data. The analysis showed no clear pattern of size- or age-related variation in GSI over the 13 month sampling period (Table 7).

The GSI data suggest that Palliser bank fish probably spawn in July-August. For large males (40–44 cm) and females (40–44 cm, ≥ 45 cm), GSI peaked in June and then decreased from September to November. For smaller length classes (≤ 29 cm, 30–34 cm), male GSI increased slightly from June to September and then decreased again by November. The GSI for the female 30–34 cm size class peaked between June and September. As male and female fish were both generally abundant on the Palliser bank from September to November, and no running ripe fish were observed in October 1985, it is most likely that peak GSI (i.e., spawning) occurs in July-August for all size and age classes. These results were unexpected because alfonsino in the Pacific and Atlantic Oceans spawn in summer to early autumn (Masuzawa *et al.* 1975, Alekseev *et al.* 1986, Sherstyukov and Nostov 1986, Uchida and Uchiyama 1986).

There appeared to be a reduction in abundance of alfonsino on the Palliser bank in July-August 1986 and an absence of running ripe fish throughout the year. This suggests that alfonsino probably spawn away from the main commercial grounds. Fish also appeared scarce on the Tuaheni Bank in August to early September 1985, though there was little fishing at this time. These observations are difficult to confirm because catch rates vary greatly at any time of the year.

Table 7: Analysis of variance to test for differences in gonadosomatic index over time within each size and age class of male and female alfonsino sampled from the Palliser bank, November 1985 to November 1986

	d.f.	*F*
Males		
Size class (cm)		
≤ 29	7, 55	2.89*
30–34	7, 73	4.56†
35–39	7, 66	1.00
40–44	7, 64	3.41†
Age class (y)		
3–05	7, 105	5.33†
6–08	7, 68	1.78
9–11	7, 47	4.42†
≥ 12‡		
Females		
Size class (cm)		
≤ 29	6, 46	2.49*
30–34	7, 76	3.13†
35–39	7, 70	1.50
40–44	7, 69	7.56†
≥ 45	7, 56	1.78
Age class (y)		
3–05	7, 105	2.51*
6–08	7, 78	1.56
9–11	7, 64	1.77
≥ 12	7, 57	2.77*

* $P < 0.05$.
† $P < 0.01$.
‡ Insufficient data.

On Japanese fishing grounds, alfonsino do not migrate away from their normal habitat to spawn (Masuzawa *et al.* 1975).

Older and larger fish may start to mature earlier than younger and smaller fish (Figures 11 and 12). Large males (40–44 cm) and females (≥ 45 cm) showed an increase in GSI as early as March, whereas the smaller size classes (e.g., 30–34 cm) did not show an increase until May or June.

The smaller male size classes (≤ 29 cm, 30–34 cm) each showed a small GSI peak in September, and both ANOVAs were statistically significant (Table 7). Several males in these classes (and the 35–39 cm class) were spermiated, though few were 29 cm or less, or 5 y or less. However, only the 40–44 cm class showed a GSI increase of the size that might be expected for spawning fish. These data suggest that though a few males may mature between 28 and 39 cm, most do not attain sexual maturity until they reach about 40 cm. The protracted range of size at first maturity and the late attainment of sexual maturity for most males seems unusual. An alternative explanation for these data is that smaller mature fish (< 40 cm) undergo their greatest gonad development away from the main commercial ground. However, for these fish to be ready for spawning, this development would need to be rapid.

Few female alfonsino showed signs of sexual maturity. The 30–34 cm size class showed an increase in GSI from June to September, which suggests gonad activity, but the 35–39 cm size class did not. The smallest stage 3 female found was 41 cm, and few were smaller than 44 cm. The mean sizes and ages at sexual maturity suggested by these data are unlikely; most fish die before they attain these lengths. It seems more likely that smaller fish do not begin developing until they are away from the main commercial grounds. In the Atlantic, Pacific, and Indian Oceans, most alfonsino attain sexual maturity (stage 3) by 5–6 y, though a few are mature at 2 y (Kotlyar 1987). In Japan, alfonsino mature at about 34 cm, or 4 y (Masuzawa *et al.* 1975). Age composition of Japanese catches varies greatly between grounds, but on the southern grounds, where most spawning occurs, most catches comprise 3–7 y fish, and few are older than 7 y. Thus, many of the fish on the Palliser bank were probably old enough to spawn.

A size-fecundity relationship was not established because a full range of sizes of fish with stage 3 ovaries was not obtained. Masuzawa *et al.* (1975) estimated the fecundity of a 40 cm alfonsino to be 300 000–500 000 eggs.

In summary, spawning may occur from July to August, with larger or older fish possibly spawning sooner than younger fish. Fish probably spawn away from the main commercial grounds. The age and size at maturity of males and females can not be determined without intensive sampling over July-August and probably not without sampling the spawning schools. Fecundity can be fully investigated only when the full size range of spawning fish can be sampled.

If alfonsino in New Zealand waters form part of an oceanic eddy population (as suggested for other stocks by Alekseev *et al.* 1986), then the east coast North Island may be a vegetative (non-reproductive) zone, where fish grow until they are near maturity and then leave for the reproductive zone. This would explain the lack of spawning fish and the steep decline in fish frequency with increasing age. It could also explain the apparently abnormal winter peak in GSI; fish in this area may start to mature in winter, which causes a rise in mean GSI, but leave the ground in spring to swim to the reproductive zone in time for summer spawning, which leaves behind immature fish with low mean GSI.

Feeding

No quantitative analyses of alfonsino diet have been done in New Zealand, but qualitative observations suggest fish (particularly myctophids) and small crustaceans are the most important food items on the Palliser bank.

Bluenose

Length frequency

Length frequency distributions of bluenose from the Palliser bank were generally similar, and the mode was between 55 and 62 cm on all except two occasions (Figure 13). The exceptions (November 1985 and 1986) had higher modes and relatively few fish between 50 and 60 cm. The sample taken in October 1985 could be interpreted as a transition between the "general" and the "November" distributions. These distributions suggest the occurrence of age- or size-dependent migration. There are no appreciable differences between the sample taken in April 1984 and those collected during 1985–86.

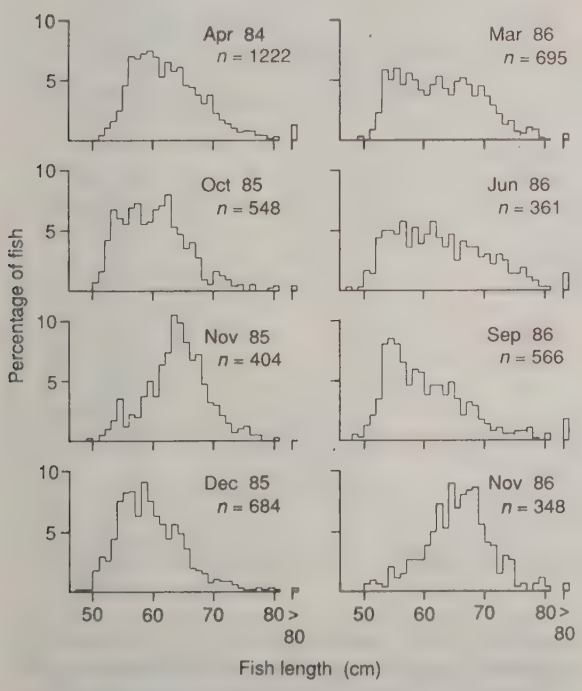

Figure 13: Length frequency histograms of bluenose samples from the Palliser bank.

Length frequency distributions of samples from all other grounds varied greatly between grounds, though there was less variation within grounds (Figure 14). Small fish were prevalent on the Tuaheni, Lachlan, and Motukura Banks and in the Madden Canyon. Large fish were more common on the Palliser bank, though most of the samples comprised fish less than 60 cm. On the Paoanui Ridge, large fish (> 60 cm) predominated. Reports from fishers also showed that mean fish size varies between grounds. A possible cause of this variation is size-specific migration, though different levels of recruitment and variation in mortality rate could also be causes.

Sex ratio

Sex ratios of bluenose samples from the Palliser bank are fairly variable, though no seasonal pattern is evident (Table 6). When all Palliser samples were combined, there was a significantly high ratio of females to males. Males were more common on northern grounds, which suggests that sex ratio may vary with latitude (Figure 15). However, the data from each of the northern grounds are based on only one or two samples from different times during the year. Female fish dominated the largest size class on all grounds (Table 8). Males dominated the smaller size classes on the northern grounds.

Age and growth

Detailed information on aging techniques and growth rates for bluenose was given by Horn (1988). The study showed that counting growth checks in otoliths is probably a valid method for aging bluenose.

Bluenose appear to be fast growing, particularly in their first 2 y, and they have a fairly short life span (few fish older than 9 y are taken by commercial fishing). The growth rate of female bluenose from all grounds was significantly higher than that for males. Von Bertalanffy parameters L_∞, K, and t_0 were, respectively, 81.1 cm, 0.308, and −0.627 for males; and 86.1 cm, 0.308, and −0.384 for females. Comparison of samples from the East Cape, the Paoanui Ridge, and the Palliser bank showed no significant regional differences in growth.

Estimates of annual natural mortality (M) derived from the observed age structures of samples (Figure 16) were misleading. For the Palliser bank and the Tuaheni Bank, the estimate of M was 0.8 (55% annual mortality), and for the Paoanui Ridge it was 0.5 (40%). These values are unrealistic; an M value greater than 0.3 would be unlikely for fish of this size and age structure. The two major factors which affect

Table 8: Sex ratios (M : F) by size class for bluenose from all Palliser bank samples combined and all other northern grounds combined

	Palliser bank		Northern grounds	
Size class (cm)	*n*	Ratio	*n*	Ratio
≤ 62	2 766	1 : 0.99	795	1 : 0.71*
63–70	1 510	1 : 1.03	239	1 : 0.49*
≥ 71	410	1 : 2.08*	207	1 : 1.33*
Total	4 686	1 : 1.07*	1 241	1 : 0.74*

* Significantly different ($P < 0.01$) from a 1 : 1 ratio.

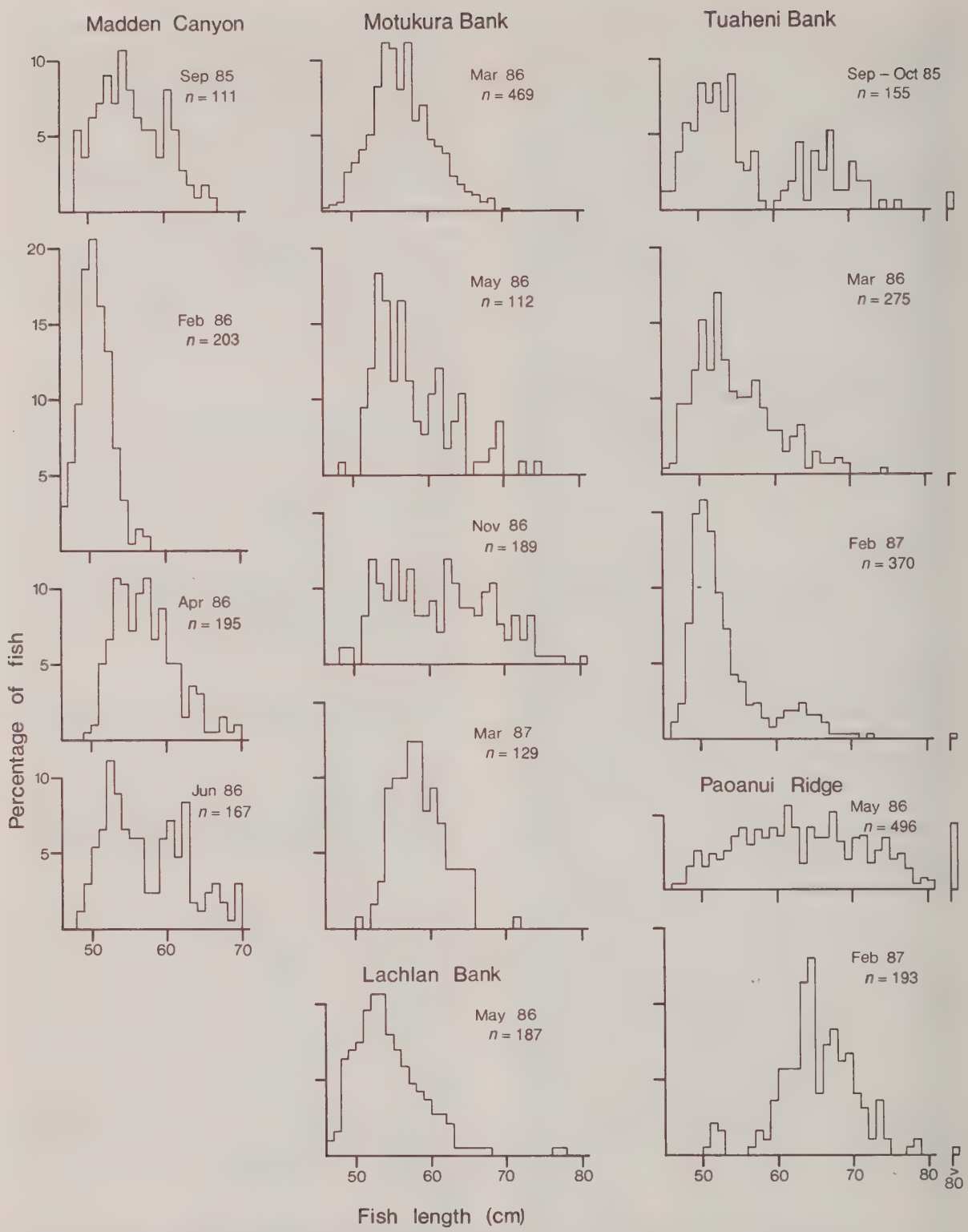

Figure 14: Length frequency histograms of bluenose samples from all grounds except the Palliser bank.

estimates of M are probably size-specific variation in vulnerability to trawl gear, and age-specific migration. Some of the older bluenose may leave the commercial grounds and move to areas that are not currently exploited, which would increase M values on the grounds they left. It may be possible to obtain more accurate estimates of mortality from tagging studies which investigate migration.

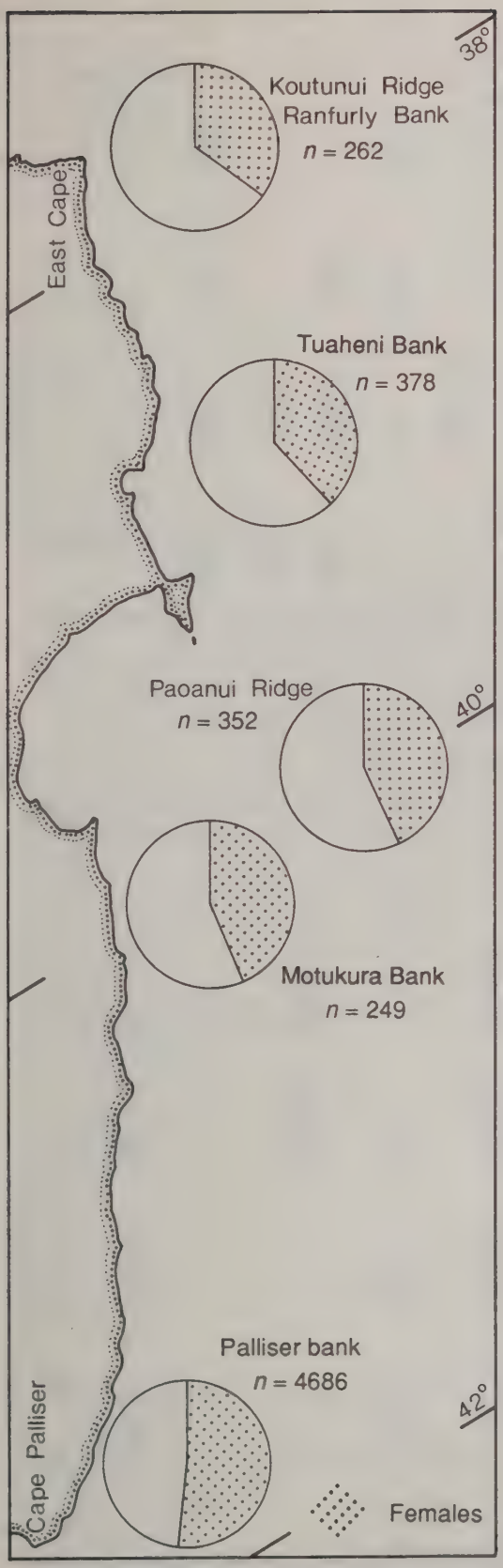

Figure 15: Sex ratios of bluenose by ground off the lower east coast, North Island.

Reproductive biology

No running ripe fish were found on the Palliser bank. Peak mean GSI occurred in November and December 1985 and November 1986 (Figures 17 and 18). These results agree with reports from commercial fishers that bluenose in the East Cape area spawn from January to April. The results are also supported by the recovery of a few running ripe male bluenose from the Paoanui Ridge, the Madden Canyon, and the Motukura Bank in early March 1987. As GSI values vary widely at any time (particularly for female bluenose), seasonal trends can be masked. An ANOVA found that none of the female size or age classes varied significantly over the sampling period. However, GSI values for most male age and size classes showed significant seasonal variation. It is likely that bluenose spawn from December until April. Jones (1985) concluded that bluenose off South Australia spawned in late April in 1984.

Spermiated (stage 3) males were present on the Palliser bank throughout the year (Figure 19). Male stages 1, 2, and 3 were difficult to classify; some gonads which were small and threadlike proved to be spermiated (stage 3), and others which were large and clearly maturing had no milt expressible (stage 2). Therefore, stages 1 and 2 were combined. Staging of gonads in male bluenose is not a good indicator of reproductive timing; GSI is a better indicator because it takes gonad size into account. Gonad stage data for males from other grounds are shown in Figure 20.

Stage 2 females were present on the Palliser bank throughout the year, but they were more common in November and December (Figure 21). Stage 3 females were rare, being present only in November and December. Only single stage 3 females were taken from the Tuaheni Bank and the Paoanui Ridge in February 1987 and the Motukura Bank in March 1986 (Figure 20). However, of a sample of 16 large (> 70 cm) females caught on the Paoanui Ridge in January 1987, 6 (38%) were stage 3 and 10 had small immature gonads.

The fecundity of bluenose could not be estimated because few female stage 3 fish were caught. The highest female GSI recorded was 5.1 for a stage 3 fish, and the highest recorded male GSI was 10.2. The relationship between age and GSI suggests that bluenose mature sexually at about 3–5 y (*see* Figures 17 and 18).

Juvenile bluenose are rarely found and are presumed to be surface-living. Fish of about 30 cm which resembled bluenose were caught by a commercial fisher on the surface above the Paoanui Ridge, but none were retained.

In summary, the reproductive biology of bluenose is still poorly understood. Spawning probably begins in late summer and may extend over a period of several months. No clear peaks in female gonad activity have been identified, and the range of GSI values varies widely at any time of the year. No distinct spawning grounds are known, and it appears that the fish may not spawn on the currently exploited grounds.

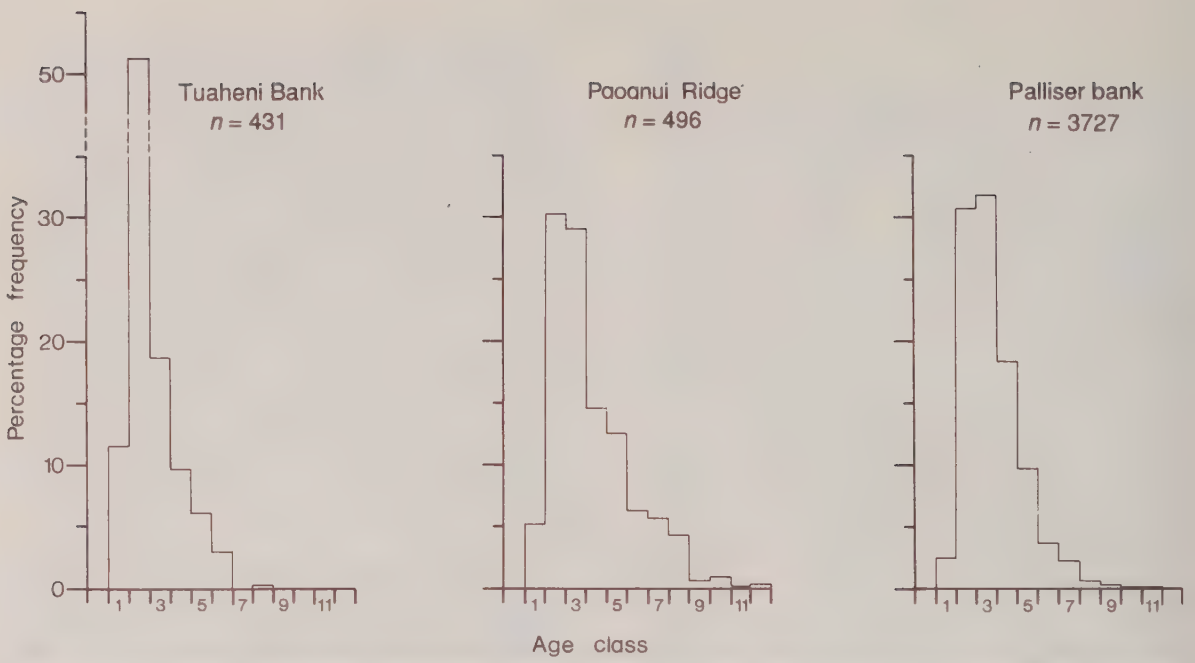

Figure 16: Age frequency distributions of commercial catches of bluenose. (The distributions were formulated by use of an age-length key as described by Holden and Raitt (1974).)

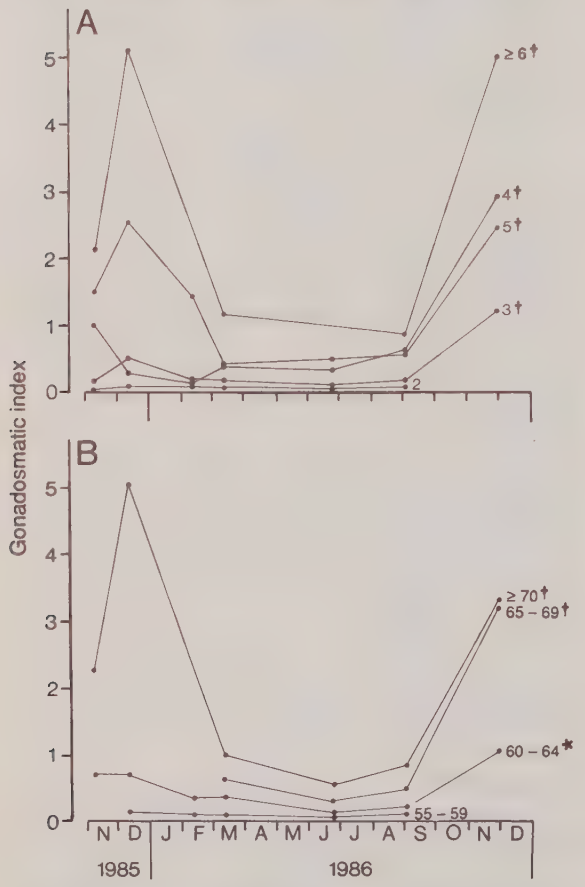

Figure 17: Monthly mean gonadosomatic indices for male bluenose from each Palliser bank sample, by age class (A) and length class (B). (Significance levels for ANOVA to test for differences in means over time within each age or length class are: *, $P < 0.05$; †, $P < 0.01$.)

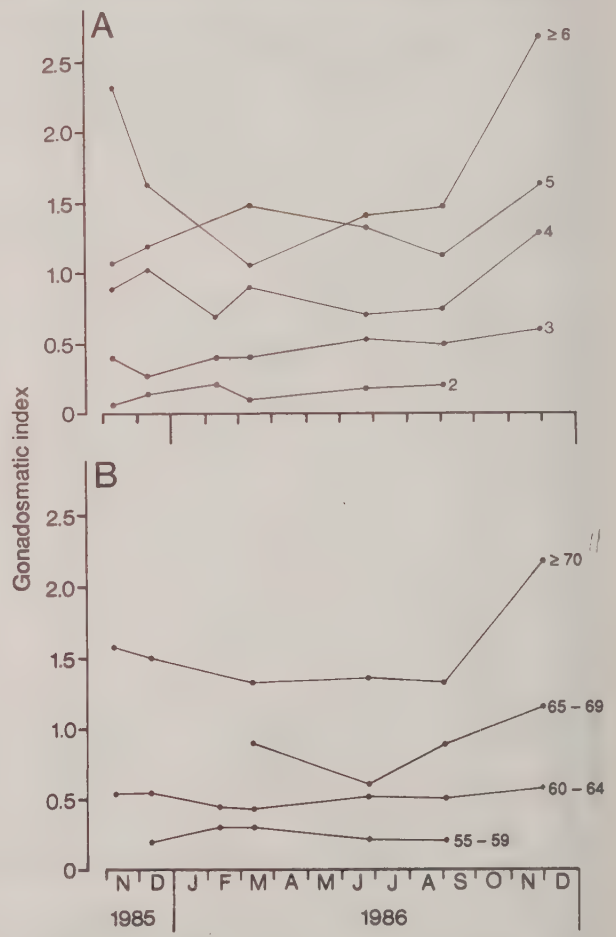

Figure 18: Monthly mean gonadosomatic indices for female bluenose from each Palliser bank sample, by age class (A) and length class (B).

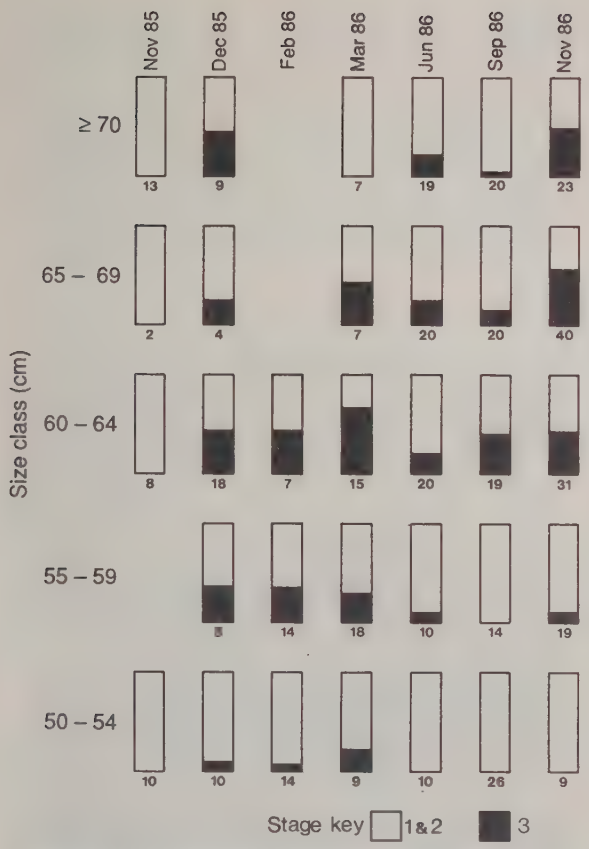

Figure 19: Gonad stage for male bluenose from the Palliser bank by length class. (Sample size is given under each bar.)

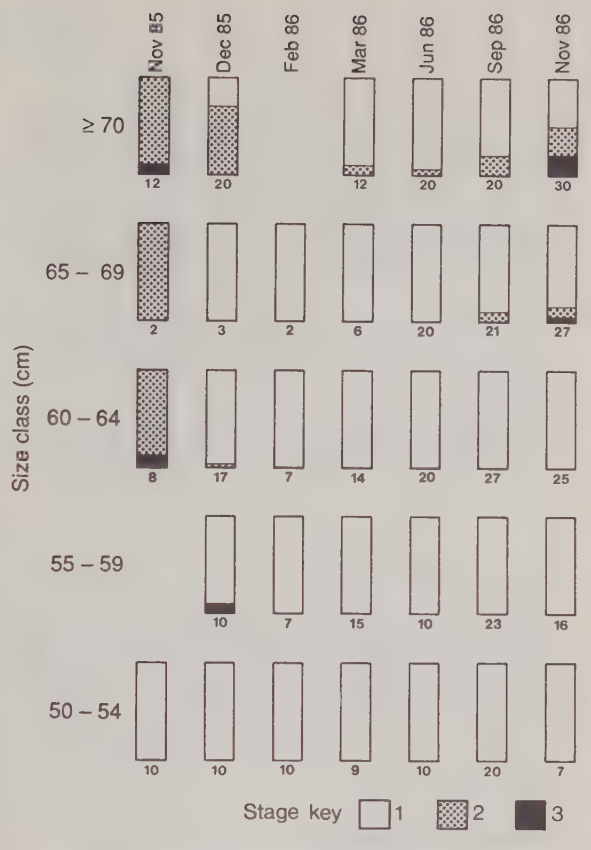

Figure 21: Gonad stage for female bluenose from the Palliser bank by length class. (Sample size is given under each bar.)

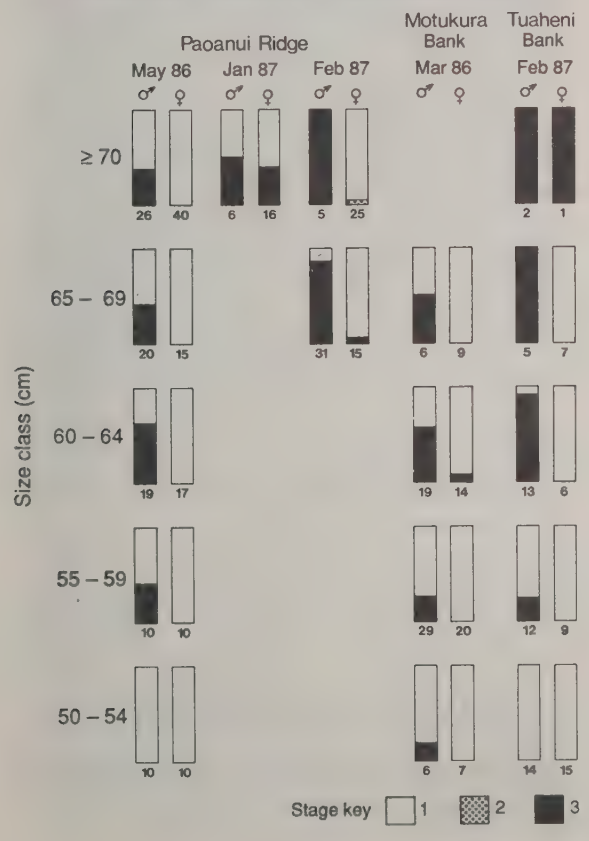

Figure 20: Gonad stage for bluenose from various grounds by length class, showing the proportions of fish of each stage. (Sample size is given under each bar.)

Feeding

No quantitative information on diet was collected in this study. However, occasional examinations of stomach contents showed that pelagic tunicates and squid were the major dietary components of bluenose from all grounds. Fish (often small hoki (*Macruronus novaezelandiae*)) were an occasional food source, and crustaceans were eaten rarely. Cestodes were found in all stomachs examined.

Abundance

There are several standard methods for assessing fish abundance. However, few were thought to be practical for this investigation. The following three projects were carried out to determine a suitable method for assessing or monitoring the abundance of alfonsino and bluenose along the east coast North Island.

1. an analysis of CPUE in the trawl and line fisheries;
2. a trawl-acoustic survey of the major alfonsino grounds;
3. a video survey.

In addition, a tagging study was carried out to examine migration of alfonsino and bluenose.

Catch per unit of effort

Catch and effort data from the trawl fishery for alfonsino and bluenose and the line fishery for bluenose in fishing return areas 011–016 were obtained from fishing return forms (*see* Figure 2). Analyses were conducted on each data set to determine whether CPUE was likely to be a useful indicator of fish abundance.

Bluenose line fishery

Catch and effort data were examined for the bluenose line fishery in the Central FMA for 1982–85. Because of the multispecies nature of this fishery, it was often difficult to tell when bluenose were targeted and when they were a bycatch. An arbitrary condition (the weight of bluenose landed had to be greater than the weight of any other single species) was used to select data for analysis. Although this condition excludes all bluenose bycatch, it may also mask declining abundance, i.e., if bluenose stocks decline to a level where previous bycatch species make up a greater catch weight than bluenose. Values of CPUE (kilograms of bluenose per hook per set) were calculated for individual boats for each fishing trip. Data for 1982–85 were analysed in three fishing return area groupings; 011–013, 014–015, and 016. Areas 014 and 015 were fished extensively by trawlers in the alfonsino fishery from late 1983. Area 016 was never trawled, and areas 011–013 produced predominantly line-caught bluenose, though the Tuaheni Bank (in area 013) was trawled from late 1984.

The CPUE data for the bluenose line fishery were skewed (Figure 22), and variances between years were heterogeneous (Cochran's test: all $P > 0.05$; Winer 1971). The raw data were transformed by log x, square root x, and x^p ($p = -0.422 = 1 - {}^{b}/_{2}$, where b is the slope of the relationship between $\log_e$ variance and $\log_e x$ (Sissenwine 1978)), and variances were re-examined. Only log x produced transformed data with homogeneous variances (Cochran's test: all $P < 0.05$) in each of the three statistical area groupings. A one-way ANOVA performed on each data set showed that there was significant variation in CPUE over time in all areas, but particularly in areas 014–015 (Table 9). The Student-Newman-Keuls (SNK) procedure (Winer 1971) was used to isolate annual means which varied significantly and to group similar annual means.

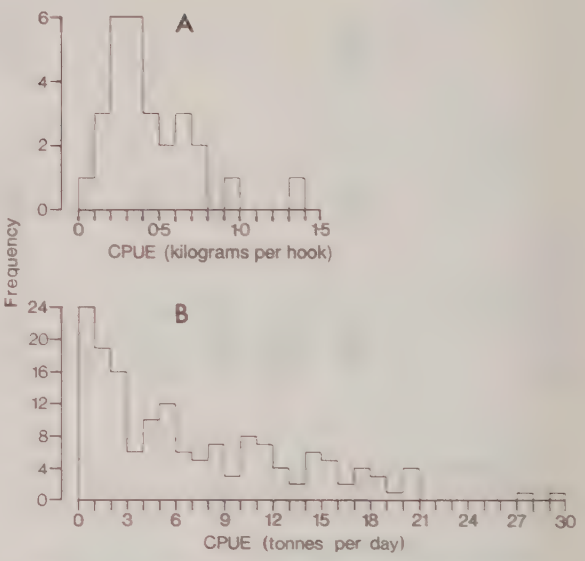

Figure 22: A, catch per unit of effort (CPUE) for line-caught bluenose from fishing return areas 014–015 in 1984; B, CPUE for trawl-caught alfonsino from the Palliser bank in 1984.

These analyses suggest that the relative abundance of bluenose has declined significantly in areas 014–015, moderately in 011–013, and has increased in 016. The SNK procedure may have failed to show which means were significantly different in areas 011–013 because the CPUE data were inadequate, or because the SNK procedure is inherently less powerful than the F-ratio of the ANOVA (Underwood 1981). Nevertheless, the trends and the timing of the changes in relative abundance correlate well with the development of the alfonsino-bluenose trawl fishery, and the deficiencies in the CPUE analysis could be rectified by including

Table 9: Catch per unit of effort data from the bluenose line fishery on the lower east coast North Island*

Year	011–013	014–015	016
1982	−0.193 (0.82)	0.018 (1.02)	–
1983	−0.392 (0.68)	−0.506 (0.60)	−1.487 (0.23)
1984	−0.903 (0.41)	−0.849 (0.43)	−1.449 (0.23)
1985	−0.912 (0.40)	−1.167 (0.31)	−0.961 (0.38)
F†	3.68	4.49	3.91
P	0.0178‡	0.0004‡	0.0299‡

* Values given are annual means of the transformed data, with back-transformed means in parentheses and similar means grouped in braces.

† F shows the degree of variation between annual means within each group.

‡ Significant variation.

more data. Analysing CPUE data from the line fishery appears to be a potential stock monitoring technique. However, many line fishers from the Central FMA have recently sold their bluenose quotas, and, consequently, future catches of bluenose in this area will be taken predominantly by trawl. Therefore, it is unlikely that continued monitoring of line fishing CPUE will provide sufficient data to gauge fish abundance, particularly in the areas of greatest trawl activity.

Trawl fishery

Catch per unit of effort data for the alfonsino-bluenose trawl fishery were calculated for each ground and for each species separately. The most suitable measure of effort for this fishery is the number of days, or part days, on which alfonsino or bluenose were targeted. A typical alfonsino fishing trip involves some search time, some target fishing, and, if fish are scarce or not visible on the sounder, some long "prospecting" tows. The measure "kilograms per day targeted" enables the data to be separated by ground, takes account of the time when fishing is not possible (e.g., because of weather or mechanical problems), and takes some account of search time (because one or two prospecting tows are often conducted even though no fish are "visible"). Catch per trip does not differentiate between grounds or account for the times when fishing is not possible. Catch per tow and catch per time towed do not account for search time, which can be long and unproductive. In addition, even if fish are fairly scarce on a ground, it is still possible to get a large catch if one of the few remaining schools is discovered and successfully targeted.

Most operators of vessels fishing in the alfonsino trawl fishery fill out tow-by-tow records which show the position of each tow and give estimates of the number of cases of each species caught. At the end of each trip, a landed catch return is filled out. The estimated number of cases of each species caught per day (midnight to midnight) on each ground can be calculated by examining each tow record. The catch per trip (from the landed catch return) is then divided by the number of cases caught per day, which gives an estimate of kilograms caught per 24 h.

Data are available from the Palliser bank for 1983–87, the Motukura Bank for 1984–87, and the Tuaheni Bank and the Paoanui Ridge for 1985–87. All catches on the Palliser bank in 1983, and some in 1984, were taken by bottom trawl; all others, including those from other grounds, were made by semipelagic trawl.

The raw CPUE data for bottom and semipelagic trawling of alfonsino and bluenose were skewed (Figure 22), and variances among the annual mean CPUEs were heterogeneous (Cochran's test: all $P > 0.05$; Winer 1971). The raw data were transformed by log $(x + 1)$, square root $(x + 0.5)$, and x^p ($p = 0.155$ for alfonsino and -0.105 for bluenose (Sissenwine 1978)), and variances were re-examined. The square root transformation produced data with homogeneous variances (Cochran's test: all $P < 0.05$) in all sets except that for bluenose from the Tuaheni Bank ($C_{(3,50)} = 0.578$, $P > 0.05$). The log and exponential transformations produced fewer data sets with homogeneous variances than the square root transformation, so all further analyses were done with square root transformed data.

The 1984 Palliser bank catches were used to compare the CPUE data from bottom trawls with those from semipelagic trawls. Mean transformed CPUE values were not significantly different for alfonsino ($t = 0.82$, d.f. = 154), but they were significantly different for bluenose ($t = 2.31$, d.f. = 156). As fewer bluenose were caught in bottom trawls than in semipelagic trawls, in later analyses only the semipelagic trawl data for bluenose (1984–87) were examined. For alfonsino, the 1984 semipelagic and bottom trawl data were combined, and data from 1983–87 were used (there were no bottom trawl data from 1985–87 for alfonsino).

A one-way ANOVA was performed on each data set (species by ground) to test for changes in CPUE with time. Significant variation occurred for alfonsino on all grounds except the Paoanui Ridge and for bluenose on the Palliser bank and the Tuaheni Bank (Table 10). The three non-significant ANOVAs were all close to being significant. Days targeted per year were calculated for each ground.

The square root transformation reduced the statistical influence of a few high daily catches, particularly for alfonsino in 1983 on the Palliser bank and in 1985 on the Paoanui Ridge. A few large catches amongst otherwise moderate catches is often a characteristic of a newly developing fishery. This occurs as fishers gain experience on each ground, which probably also explains the initial rise in CPUE in the second year of exploitation on some grounds. However, for both species and on all grounds, CPUE showed a general decline after the initial peak.

Despite the predominance of statistically significant ANOVAs for yearly means, the SNK procedure often showed no significant difference between means. As for the bluenose line fishery, this was probably because the SNK procedure is less powerful than the F-ratio of ANOVAs (Underwood 1981).

In general, the CPUE data were highly variable, which was probably caused by the variability of several factors, including vessel size and power, technology, and skipper experience. In addition, fish behaviour can substantially alter availability of fish over short terms. The reliability of CPUE analyses could be increased by the use of additional data and by attempting to remove the variance in the data.

Several aspects peculiar to the alfonsino-bluenose fishery may also bias CPUE. More days are spent targeting on the Palliser bank than on any other ground. In addition, other grounds may be fished only when fishing is poor on the Palliser bank. Consequently, if fish availability is related to some macroscale characteristic (e.g., weather or lunar cycle), rather than individual ground characteristics, then grounds other than the Palliser bank may not be being

fished randomly in relation to the availability of fish on them. The change in fishing patterns over time may also have influenced CPUE. When fewer grounds were fished, more time would have been spent on searching and prospecting. In later years, the grounds would have been searched more quickly, and a lower catch per day would have been taken from fewer prospecting tows. However, this bias would have occurred only before 1985. It is also possible that fishing pressure has modified fish behaviour in ways that have reduced fish availability. Alfonsino and bluenose may have become more wary of the trawl; fishers involved in the fishery for several years have commented that alfonsino, in particular, are now more "flighty" and less abundant. Fish could also have moved off the trawl grounds, though alfonsino are less likely than bluenose to do this because they prefer fewer areas.

It is unlikely that these factors alone could have caused changes to the extent seen on all grounds for alfonsino and bluenose. Although declines in CPUE suggest declines in fish abundance, they may slightly overestimate the actual declines in stock sizes. Stocks of alfonsino and bluenose appear to be at about one-third of their levels before the development of the alfonsino-bluenose trawl fishery.

In summary, the analysis of CPUE data from the trawl fishery appears to be a useful method for determining the relative abundance of alfonsino and bluenose on the trawl grounds.

Trawl-acoustic survey

Background

Biomass estimates of demersal species have frequently been calculated from catch and area-swept data from bottom trawl surveys. To obtain absolute population estimates, many assumptions about trawl efficiency are made, including effective area swept and trawl height. Furthermore, because of the variable behaviour and patchy distribution of the target species, fish density needs to be high to ensure abundance estimates with low variances.

Echo integration is also used as a stock assessment technique. However, it is a complicated technique because the target schools are often of mixed species and large quantities of plankton and micronekton also return echoes.

Because of the difficulties involved with these techniques, neither a trawl nor an acoustic survey was thought useful for the stock assessment of alfonsino and bluenose. However, a combined trawl and acoustic technique, which allowed calibration of acoustic data with trawl catches, was thought to be feasible and was formulated.

The main aims were:

1. to test the suitability of the technique for estimating the absolute abundances of alfonsino and bluenose in the Central (East) FMA;
2. to map the distribution and abundance of alfonsino between the Tuaheni Bank and the Palliser bank;
3. to determine what factors influence the abundance of alfonsino.

The secondary aims of the survey were:

1. to map the distribution and abundance of bluenose in the study area;
2. to provide an estimate of the biomass of alfonsino and bluenose in the study area.

Methodology

The survey comprised four cruises in January-March 1986. The first two were on *Marine Star II*, a 23 m stern trawler chartered from J. Wattie Canneries Ltd., Gisborne. A Furuno paper sounder and a Koden colour sounder were used to locate the fish, and a midwater trawl net with a headline height of about 15 m and a wingtip spread of 23 m was used. The last two cruises were on *Resolution II*, a 27 m stern trawler chartered from Skeggs Foods Ltd., Nelson. It was equipped with a Furuno colour sounder and a French "Anza" semipelagic trawl net with a headline height and wingtip spread of 30 m. A detailed diary of the cruises was given by Massey and Horn (1986).

Individual grounds within the study area (*see* Figure 2) were surveyed for one to three nights, depending on their size. On the first night, a pre-determined grid of transects was surveyed with the echosounder. When a school of fish was encountered, it was surveyed in at least two different directions to enable its size to be estimated. Each school on the colour sounder was also graded according to an arbitrary density scale (Appendix 1). In addition, the schools were divided into two types: A, those with clear boundaries and B, those with unclear boundaries.

From these data the number of schools on the ground during the night, the volume of each school, the relative density of the schools, and the depth strata each school was occupying were estimated. The ground was resurveyed in the same manner the following day to enable a direct day-night comparison to be made.

On the second night, two randomly chosen transects were resurveyed and any schools encountered were trawled. Trawl shots were also done randomly in various depth strata between schools. The data collected were used to estimate the amount of fish in each school and the approximate density of fish within and between schools on that ground.

Results and discussion

Acoustic data

Many marks were recorded on sounder traces during the grid surveys and while grounds were being searched for fish. The number and estimated density of all schools (types A and B) observed during the survey, relative to time of day, are given in Table 11. However, many of these schools may not have been alfonsino and bluenose. Shallow schools could have been hoki and deeper schools cardinal fish (*Epigonus*

Table 10: Catch per unit of effort data from the alfonsino-bluenose trawl fishery*

Year	Palliser bank	Motukura Bank	Tuaheni Bank	Paoanui Ridge
Alfonsino				
1983	80.25 (6 439)			
1984	73.16 (5 352)	81.30 (6 604)		
1985	54.97 (3 021)	52.09 (2 713)	94.22 (8 877)	47.02 (2 211)
1986	60.71 (3 685)	53.49 (2 861)	69.65 (4 850)	65.82 (4 331)
1987	52.32 (2 728)	39.66 (1 573)	29.49 (869)	50.72 (2 572)
F†	8.03	5.622	15.79	2.34
P	0.0001‡	0.0012‡	0.0001‡	0.1014
Bluenose				
1984	43.29 (1 874)	39.59 (1 567)		
1985	38.04 (1 447)	53.68 (2 881)	46.26 (2 139)	66.32 (4 398)
1986	39.02 (1 522)	36.35 (1 321)	34.04 (1 158)	77.21 (5 961)
1987	28.04 (786)	29.92 (895)	17.23 (296)	53.58 (2 871)
F	6.52	2.39	7.61	2.57
P	0.0003‡	0.0722	0.0009‡	0.0817
Days targeted				
1983	73			
1984	169	35		
1985	46	23	31	13
1986	103	59	58	44
1987	122	29	16	48

* Values given are annual means of the transformed data, with back-transformed means in parentheses and similar means grouped in braces.
† *F* shows the degree of variation between annual means within each group.
‡ Significant variation.

Table 11: Number of schools observed by time of day, depth, and density index

Time*	Bottom† depth	Density‡ of schools on or less than 30 m off bottom				Density of schools more than 30 m off bottom				Total schools	Mean density of schools
		1	2	3	4	1	2	3	4		
0000–	1	1	1	6	–	6	6	9	3	32	
0600	2	1	1	4	–	–	–	4	1	11	2.5
	3	–	–	–	–	–	–	–	–	0	
0600–	1	1	2	1	–	–	–	2	–	6	
1200	2	–	2	6	1	1	–	1	–	11	2.3
	3	2	–	1	–	1	2	–	–	6	
1200–	1	8	4	9	2	–	–	1	1	25	
1800	2	2	2	2	5	–	–	–	–	11	2.5
	3	–	–	3	1	1	1	1	–	7	
1800–	1	–	–	3	–	–	–	3	5	11	
2400	2	–	–	–	–	–	–	1	–	1	3.2
	3	–	2	–	–	–	–	–	–	2	

* New Zealand Standard Time.
† 1, 200–400 m; 2, 401–600 m; 3, 601–800 m.
‡ *See* Appendix 1.

telescopus), and the diffuse marks could have been plankton or micronekton. Estimated mean school volumes on the Motukura and Palliser grounds are given in Table 12. (Mean school volume, rather than number of schools present, was used because it is more useful for relative abundance estimations.) The data show that for the schools surveyed:

1. The number of schools decreased with increasing depth.
2. Schools were generally off the bottom during the night.
3. Schools were generally on, or near, the bottom during the day, particularly in the afternoon.
4. About the same number of schools was seen during the day and the night.
5. The mean volume of the most dense schools (density index 1) was greater at night than during the day.

Trawl data

Bad weather and frequent inability to catch schools seen on the sounder meant that insufficient trawl data were obtained to adequately interpret the composition and density of schools observed. Many of the schools encountered (especially the less dense ones) were probably not alfonsino-bluenose schools.

A summary of the trawl shots done from *Resolution II* shows the variability of catches between tows and days (Table 13). Trawl shots from *Marine Star II* were not included because they were generally unsuccessful (i.e., the catch did not represent the marks seen on the echosounder). The effective tow period was the period during which the net was towed through a school (determined from the net monitor trace), or, for random tows, the period between when power was applied, to avoid the net hitting the bottom, and when the gear was hauled.

Whenever possible, estimates were made of catch rates in individual schools and of fish density. Data from target tows were used only if the net monitor trace showed the net had passed through the school. Densities of the school categories are given in Table 14, and they were calculated by assuming:

1. The net mouth area was 30 × 30 m.
2. All tows were done at 3 kn.
3. All fish in front of the net mouth were caught.
4. Fish were not herded into the net mouth.
5. No escapement occurred.

Table 12: Calculated mean volume ($10^6 m^3$) of all schools in each of the four density categories, as observed during day and night grids on the Motukura Bank and the Palliser bank

		School density index†			
Ground	Time*	1	2	3	4
Motukura Bank	1800–0600 (night)	15	23	16	8
	0600–1800 (day)	0	65	47	68
Palliser bank	1800–0600 (night)	140	39	194	0
	0600–1800 (day)	17	199	975	94

* New Zealand Standard Time.
† *See* Appendix 1.

Estimated densities of all school types were low. The greatest density of fish calculated for any tow was 36.7×10^{-4} kg.m^{-3}, which corresponds to about one fish in every 470 m^3. As it is unlikely that this density of fish would give the solid mark seen on the sounder for this tow, the efficiency of the trawl may have been much lower than expected. Therefore, it is probably not possible to get good estimates of absolute density if the area-swept volume method is used.

Some random trawl shots were done between target shots. They were made in areas where no fish showed on the sounder to enable relative densities of alfonsino and bluenose in and out of fish schools to be estimated. No alfonsino or bluenose were taken in any of these shots, which suggests that the abundance of these species on the alfonsino fishing grounds is very low outside fish schools.

Occasionally, when a school of fish was found, several shots were done over roughly the same trawl path to assess the change in school density and composition with time. The total catch rate and the catch rate of each species for these tows are shown in Figure 23. Catch rates generally increased during the

Table 13: Summary of tows done by the fishing vessel *Resolution II*, March 1986

			Species (kg)					
Time*	Date	Locality†	Alfonsino	Bluenose	Hoki	Gemfish	Southern boarfish	Total
1605	5/3	P	330	2	25	2	–	359
1922	5/3	P	30	25	35	30	–	120
2128	5/3	P	25	15	35	3	–	85
0002	6/3	P	780	50	15	3	–	848
1241	6/3	K	–	50	15	–	–	80
0351	8/3	M	3 360	1 000	17	120	–	4 496
0644	8/3	M	15	1 500	–	–	–	1 730
0936	8/3	M	–	3	–	4	–	26
2003	8/3	M	30	375	2	45	–	452
–‡	9/3							
2107	9/3	T	810	175	–	7	30	1 025
2352	9/3	T	6 000	1 975	–	60	120	8 155
0247	10/3	T	12 870	2 425	–	30	120	15 445
–‡	10/3	T						
0725	10/3	T	3	–	–	–	–	4
2004	10/3	T	1 290	100	–	–	90	1 510
2225	10/3	T	1 710	100	–	–	30	1 855
0040	11/3	T	240	50	–	–	–	290
0425	12/3	P	420	5 540	–	300	–	6 170
0710	12/3	P	2 400	1 375	–	210	–	3 985
Subtotal§			30 913	14 670	144	844	390	46 635
0804	18/3	P	120	50	70	30	–	270
2034	18/3	P	210	7	20	20	–	257
2318¶	18/3	P	–	–	560	–	–	570
0111	19/3	P	720	675	–	90	–	1 485
0401¶	19/3	P	–	–	140	–	–	219
0603	19/3	P	360	1 575	30	60	–	2 041
1938¶	19/3	P	–	–	10	2	–	20
2241¶	19/3	P	–	–	105	–	–	132
0055	20/3	P	540	100	20	30	–	700
0244¶	20/3	P	–	–	35	–	–	35
1848	20/3	M	6	40	–	2	–	50
Subtotal			1 956	2 447	990	234	–	5 779
Total			32 869	17 117	1 134	1 078	390	52 414

* Time (New Zealand Standard Time) is the midpoint of the effective tow period.
† P, Palliser bank; K, Kaiwhata Bank; M, Motukura Bank; T, Tuaheni Bank.
‡ Gear came fast.
§ Subtotals give results for trips three and four separately.
¶ Random tows.

Table 14: Mean densities (10^4kg.m^{-3})* of alfonsino (BYX), bluenose (BNS), and total fish in each school category

School type†	Density index‡	*n*	BYX	BNS	Total
A	2	2	5.06 (1.74)	0.13 (0.08)	5.50 (1.89)
	3	3	3.60 (0.26)	1.39 (1.05)	5.52 (1.09)
	4	2	0.01 (0.01)	1.19 (0.97)	1.26 (1.22)
	5	2	0.07 (0.03)	0.58 (0.58)	0.72 (0.68)
B	2	2	27.56 (0.59)	7.09 (1.79)	35.22 (1.44)
	3	7	4.40 (1.43)	4.07 (2.70)	8.86 (3.01)
	4	3	0.72 (0.57)	0.33 (0.22)	1.77 (1.20)

* Standard errors are in parentheses.
† A, clear boundaries; B, unclear boundaries.
‡ *See* Appendix 1.

first few hours of darkness and decreased towards dawn. These results must be interpreted cautiously because few tows were made. However, when compared with the acoustic data, they suggest that alfonsino-bluenose schools are more prevalent and more dense at night than during the day.

The trawl shots gave some information on bycatch rates. Hoki were usually taken as a significant bycatch on the Palliser bank, but they were rarely taken on the Tuaheni Bank. Conversely, southern boarfish (*Pseudopentaceros richardsoni*) and red bream were common on the Tuaheni Bank and the Motukura Bank, but they were never found on the Palliser bank. Gemfish (*Rexea solandri*) catch rates were more consistent between grounds than those of the other significant species.

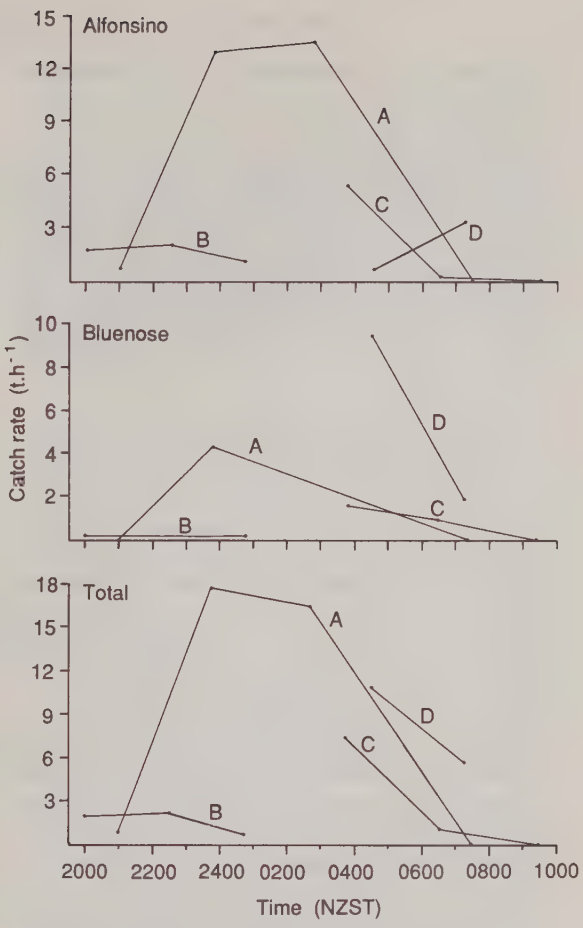

Figure 23: Catch rates for alfonsino, bluenose, and total catch, from consecutive tows done over roughly the same path. (A, Tuaheni Bank, 9–10 March; B, Tuaheni Bank, 10–11 March; C, Motukura Bank, 8 March; D, Palliser bank, 12 March.)

Conclusions

Galaktionov (1984) found that adult alfonsino schools were distributed near the bottom during the day (1000–1700 h), formed into large dense aggregates above the bottom in the early evening, and then ascended well above the bottom before breaking up completely. The reverse procedure occurred during the early morning. Galaktionov stated that the main features of school behaviour were retained by pre-spawning and spawning fish. This pattern of alfonsino behaviour was not observed during the trawl-acoustic survey reported here. The reverse pattern (fish on the bottom during the evening formed a large dense aggregate at dawn before ascending and dispersing) was observed on two successive days on the Palliser bank. However, no single or consistent pattern of behaviour can yet be attributed to alfonsino-bluenose schools in New Zealand waters.

School volume can be readily estimated from the echosounder. The arbitrary density scale was adequate, though a numerical scale based on returned voltages would measure density of schools more precisely. More accurate estimates of school volume could be achieved by the use of research sounders with narrower beam angles and higher resolution than commercial sounders, though commercial echosounders do not limit the accuracy of biomass estimates.

The main problem with the methodology tested in this study was that trawling was inadequate for estimating the density of fish within schools. This is because the performance of the trawl is unknown and apparently quite variable, and it is impractical to estimate trawl efficiency for each tow made during a survey. Average trawl efficiency probably has little meaning when efficiency varies so greatly between tows. In addition, trawling is inadequate as a method for identifying the species composition of schools, e.g., when a mark is trawled and the net comes up empty, it cannot be assumed that the mark was plankton or micronekton, it could have been an alfonsino-bluenose school which evaded the net. There were usually some fish present on a ground, but the amount varied from insignificant quantities to large schools. Large variations occurred from night to night, and even on those nights when fish were abundant, catch rates could vary substantially between shots. Therefore, the timing of survey work is crucial. A ground must be surveyed when fish are available if accurate biomass estimates are to be made; however, at present we are unable to predict when fish are available, and this creates major problems for any survey, regardless of the methodology used.

Video survey

To acquire more information on the composition of the observed acoustic marks, a video camera was put into each mark.

Two surveys to test the feasibility of using video cameras for school identification were carried out from the research vessel *Kaharoa* in September and October 1986. Once a school was found, the vessel steamed across it, and its size and apparent density were determined from echosounder marks. The vessel was then stationed over the school and the video camera and light, both mounted on a frame, were lowered through the mark.

Unfortunately, bad weather and mechanical problems shortened both trips. However, on the three surveys when filming was possible, video drops were carried out successfully. During the first trip, several large marks were present, and there was usually no difficulty in maintaining the vessel above the mark. Although strong currents sometimes carried the camera away from the vessel, it would have been in the school most of the time. A commercial vessel operating on the seamount at the same time was obtaining good catches. Although they did not tow through any of the marks being filmed (they did attempt this once, but strong tides carried them off the mark), the skipper of the commercial vessel commented that one mark being worked on for a long time appeared to be an alfonsino-bluenose school.

Despite repeated attempts, filming fish within the schools was generally unsuccessful. Even when the light was turned off for an extended period and then turned back on suddenly, fish were not seen on the TV monitor. Only on one occasion were fish filmed, and most of these were too far away from the camera to be identified.

It is probable that at least some of the marks being worked on were alfonsino-bluenose schools. The limited success of filming fish on the first trip suggested that both species were deterred by the presence of the camera, light, and frame, rather than by the light itself. The best alternative may be to tow the camera through the marks at 2–3 kn; fish would then be less capable of avoiding the camera.

Tagging surveys

Biological investigations showed that both alfonsino and bluenose probably migrate between grounds. Understanding migration patterns is important for the identification of stock boundaries and the interpretation of existing abundance, age structure, and growth data. Between February and October 1987, alfonsino and bluenose were tagged with detachable hook tags in an attempt to determine the migration patterns of both species. A detailed description of this programme was given by Horn (1989).

A pilot study was conducted to determine the best hook type, tag design, and breakable trace strength for the fishery. A yellow streamer tag, attached by a 10 cm length of malleable wire to a stainless steel circle hook, fished on a 5.5 kg breaking strain nylon trace, was the best gear configuration.

Fish were tagged on six grounds between Gisborne and Cape Palliser. Between 347 and 496 tags were lost on each of the four main alfonsino grounds (Palliser bank, Motukura Bank, Paoanui Ridge, Tuaheni Bank), and 323 and 30 tags were lost in the Madden Canyon and on the Kaiwhata Bank, respectively. Control lines, set adjacent to the tagging lines, caught 313 fish, 260 of which were bluenose. The rest of the catch comprised commercial and non-commercial species, including 10 alfonsino.

By 31 May 1989, 47 (2.2%) of the 2122 tags lost had been returned, most were from bluenose. Bluenose did not show any patterns of migration; all but four of the tagged fish were caught on the ground where they were tagged. It appears likely that few alfonsino were tagged in this programme, and no useful information on alfonsino movement has yet been obtained.

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Appendix 1

Density scale for trawl-acoustic survey

Density index	Colour sounder mark	Density
1	Solid reddish-brown	High
2	Mostly reddish-brown	Medium high
3	Mostly light colours	Medium
4	Light spots only	Medium low
5	Light haze	Low

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